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THE DEVELOPMENT OF MINERAL INDUSTRY EDUCATION IN THE UNITED STATES

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The Seeley W. Mudd Series

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Edited by The Committee on the Industrial Minerals Volume

ELEMENTS OF THE PETROLEUM INDUSTRY
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THE DEVELOPMENT OF MINERAL INDUSTRY EDUCATION IN THE UNITED STATES
By Thomas Thornton Read

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The Development of Mineral Industry Education in the United States

BY

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41-27303

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Foreword by
HERBERT HOOVER

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TO THE MEMORY OF

JAMES FURMAN KEMP

Educated as a mining engineer, he became
an economic geologist of international reputation,
who not only contributed much to the development of that
field of applied science, but, as a teacher, supplied
inspiration and enthusiasm to young men in sending
them out to play their part in utilizing
mineral substances to promote the
welfare of mankind

PREFACE

IT is most appropriate that this study of the progressive development of educational work accessory to mineral industry should be published by the American Institute of Mining and Metallurgical Engineers, since it is a direct result of the activities of the Mineral Industry Education Division of the Institute. Shortly after that Division was organized, on Jan. 15, 1932, two facts became evident. The first was that the men engaged in educational work in this field typically thought of themselves as technologists, and only secondarily (or not at all) as educators. The second was that a lack of a common background of general knowledge on the broad subject of education for the mineral industries hampered discussion of educational problems. This was a natural result of the first condition, since no one had taken the time to study the whole field from any viewpoint other than technical content of curricula. The general subject of education has been subjected to much professional study, and it seemed important that the field of special education for the mineral industries should no longer lie fallow.

Although, for convenience's sake, this work bears the cover title "Mineral Industry Education," the limitations of time have restricted it to a study of development in the United States, with only such discussion of its earlier phases in Europe as was necessary to provide the background for our own history. There is some justification for the use of the general title, however, in the fact that although systematic instruction accessory to the mineral industries was not initiated here until a hundred years after it had begun in Europe, once started it progressed much farther. The more than fifty academic institutions which contribute to it here must represent more than half of the total for the world; at least in the number of students, equipment for instruction, and the quality of the instruction itself, even if they do not constitute a numerical majority of all schools that offer some instruction accessory to mineral industry. The latter is obviously a category for which it is difficult to determine the limits of inclusion.

Readers will notice that a much greater amount of space is devoted to some schools than to others, and may guess that the principal reason for this unevenness lies in the author's inability to secure equally full data on all of the institutions. This was indeed the case. There is much published material regarding some schools, while for others little is available except the files of catalogues in the Teachers College library. Personal friends who are graduates of such schools have furnished invaluable aid in some instances, but in others no such help was available. Some schools, also, were much more important than others in their influence on general development, and an effort has been made to achieve some reasonable balance in that regard. The large amount of space and attention given to the Columbia School of Mines would perhaps seem justified because it was the first conspicuously successful School of Mines in the United States, and had a corresponding influence on development elsewhere. Another reason for repeated reference to it is that the author is much more sure of his ground in using occurrences there to illustrate what appear to be general forces and trends, as well as the influences of special conditions on development. Finally, it is not generally known that it was in organization, almost from the beginning, a general school of technology, rather than a school of mines, and it seemed necessary to make that clear because of its bearing on the discussion of the relations between general science education and mineral industry education on the one hand, and between mineral industry education and general engineering education on the other.

It may seem to some that too much attention has been paid to the organization of technical instruction, rather than to its content and conduct. The reason for this is the author's belief that organization has had an important, and at times a controlling, influence on content and conduct, and therefore deserves the emphasis accorded it. Longer and more intensive study of the subject might have led to the presentation of somewhat different views, but pressure of other matters precluded such a course. Early training as a geologist also suggested that the proper course to pursue is to publish the results of a study of a field, rather than to delay, so depriving later investigators of the benefit of what is already known. The imperfect early studies of ore deposits made possible the more advanced knowledge of today.

The problem of acknowledgment of aid, always a puzzling one, is peculiarly difficult in this case, since to mention by name all the friends with whom correspondence has been carried on over a period of several years would make a list so long as to defeat its very end. It would be invidious to attempt to distinguish between those who have furnished easily accessible material and those who have gone to considerable trouble to procure it. In several of the latter instances footnotes throughout the text indicate special aid of this sort. Perhaps it will suffice to say that the author is indebted to nearly everyone actively engaged in mineral industry education today, but that to A. C. Callen, E. A. Holbrook, Charles E. Locke, Dorsey Lyon, W. B. Plank, F. A. Thomson, George B. Waterhouse, and L. C. Uren, who have read and commented on the whole text in addition to contributing data, special thanks are due.

Acknowledgment is gladly made to the Seeley W. Mudd Memorial Fund of the Institute for financing the publication. The purpose of that fund is to provide "for the advancement of the sciences of mining and metallurgy by the encouragement of research and the dissemination of knowledge and for the promotion of the welfare of engineers engaged in the professions of mining and metallurgy. Inasmuch as Mr. Mudd was more closely identified with nonferrous mining and metallurgy and always sought by his counsel and interest to guide and encourage the younger men of the profession, the donors express the wish, but without imposing any restrictions, that the Institute will give preference to research within the nonferrous field and which will be of particular benefit to young engineers." Since the basic reason for making this study was the hope of benefiting young engineers through contributing to the development of better educational facilities for them, the association is a gratifying one.

A final word must be said as to the frontispiece. One of the large buildings recently provided from public funds for mineral industry education might have been selected for that conspicuous position, but since the mineral industry of the United States has reached its remarkable stage of modern development as a result of private enterprise, under the leadership of outstanding men, it seemed fitting to give that place of honor to a building given to the public by a great mining corporation; the more especially since it commemorates one of the men in the mineral industry who held the respect and admiration of all who were privileged to know him. Educated first for the Christian ministry and later for the medical profession, but called by the pressure of circumstance to engage in metallurgical enterprise, James Douglas brought to his years of outstanding work in that field a high personal as well as intellectual integrity and a generosity of character that will make him long remembered. In selecting the building that commemorates him as typical of the physical aspects of mineral industry education, the author hopes to imply that mineral industry education will be most worth while if it produces men of the type of James Douglas.

Thomas T. Read.

Columbia University, New York,
May, 1941.

FOREWORD

IN the year 1556 the first systematic treatise upon engineering, chemistry, law and something on medicine in relation to mining was published under the title "De Re Metallica," by Georgius Agricola. Agricola called his exposition a discussion of the "many arts and sciences of which the miner must not be ignorant." The book was in Latin. But translated into many languages, it became the center around which innumerable groups were taught over two centuries the beginnings of these sciences. Chained to the altars of the churches in the days of the Spanish Conquest, it was translated and expounded by the priests of the first Spanish miners. Here, perhaps, first began technical education.

Indeed, a large part of early engineering and chemistry had its origins in the mines. The beginnings of systematic engineering training began with the Old World mining schools established during the eighteenth century. These schools were largely to train minor officials for the state-controlled or state-owned mines. Engineering as a profession received its real establishment in the New World. Socially, officially, and economically, the builders of cathedrals, the operators of mines, the makers of bridges and ships were regarded as artisans until well within the nineteenth century.

My own impression is that it was not until the American universities embraced engineering as a full part of their work that engineering took upon the full dignity of a profession. The major demarcation between an artisan and an engineer is not alone the actual technical knowledge. It is the recognition of the qualifications of broad education and obedience to a code of ethics. Anyway, the British universities refused to incorporate engineering into their curricula until much later than the Americans. In the meantime, the American engineers—especially the mining engineers—flooded the British Empire.

The production of metals and minerals involves all the physical sciences. Its daily need is economics and sociology. It requires character and breadth in men to which all the humanities must contribute.

As Georgius Agricola says, "insomuch as the calling of the miner excels in honor and dignity that of the merchant trading for lucre, while it is not less noble though far more profitable than agriculture, who can fail to realize that mining is a calling of peculiar dignity," and one that calls for intensive educational preparation.

Professor Read has done honor to the profession and has contributed to strengthen its foundations by this book.

HERBERT HOOVER.

January 11, 1941.

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THE DEVELOPMENT OF
MINERAL INDUSTRY EDUCATION
IN THE UNITED STATES

THE DEVELOPMENT OF MINERAL INDUSTRY EDUCATION IN THE UNITED STATES

CHAPTER 1

THE BEGINNINGS OF MINERAL INDUSTRY EDUCATION

THE education of adolescents to perform the duties and assume the responsibilities of maturity has been a characteristic of human society since the dawn of history. In the beginning the members of the immediate family performed this function, and in modern life they still have an important part in it. Possibly religion was the first field in which education began to be functional; young people were sent for instruction to a teacher who had a broader and deeper knowledge of the subject than was possessed by the family. It does not seem necessary for our purpose to attempt to determine how, when, or where instruction in the practical arts first began to become functional, and the brief outline which follows must suffice.

The discovery and utilization of mineral substances to improve and maintain the conditions of human living is a practical art, which must have had an almost accidental origin and have been developed by empirical experiments. We do not know, nor would it be useful to try to fancy, how men first learned that they could make use of mineral substances to their benefit, but however that knowledge was initially gained it was certainly transmitted through instruction in the family. At first such activities must have been merely a minor part of the making of a living, but in time those who excelled found it better to devote themselves almost wholly to such arts, and obtain other needed commodities through exchange. The mineral arts and crafts were thus born and young persons not members of the family began to be admitted into a group which had its basis in a common purpose and service.

Once admitted to such a group the young person might either remain permanently in it, or return to his kindred after he had learned its techniques. Where the primary function of such a group was the making of a living the former would usually be the better course to pursue, but where the group's main objective was teaching, support must be provided during this period, and the student eventually return to his main business of making a living. Until quite recent times it was possible for a young man to support himself as a clerk in a lawyer's office, "read law," and be admitted to the bar without having attended a law school. Lawyers were not averse to thus training potential competitors, but in the field of practical arts the number of apprentices was usually restricted to the estimated future needs of the business.

It would require too much space to mention all the factors which led to the result that schools, groups devoted to teaching, typically concerned themselves with those matters that are loosely termed "the humanities" until after the Middle Ages, while the practical arts, among them the making of mineral substances useful to man, were learned only by working in them. This relationship might have persisted if the arts had remained static, but actually they were steadily advancing, so that one group knew more than the others. It jealously guarded that advanced knowledge and the curiosity of the others as to how a superior result was attained furnished the incentive for systematic study. So the theoretical study of technology, as distinguished from the teaching of a technique by a master craftsman, was born.

The learning of mineral technology remained essentially upon the latter basis until after the Middle Ages, with individual exceptions, such as the eleventh century monk, Theophilus Rugerus, who extended his interest in the use of metals in the construction and decoration of churches to learning how the metals were obtained from their ores. It entered upon what may be called its literate stage with the publication of George

Bauer's "Bermannus" at Basel in 1530, "a sort of catechism on mineralogy, mining terms, and mining lore," and was more firmly established there by his later works. The most important of these are "De Ortu et Causis Subterraneorum," the first book which deserves to be described as physical geology; "De Natura Fossilium," the first systematic mineralogy (both of which appeared in 1546); and "De Re Metallica," which was published in 1556.

The significant thing about Bauer's publications is that he was a practicing physician, not a mineral technologist, though evidently he had financial interests in mines. He states in the dedication of "De Re Metallica"[1] to various princes that his intention was to do for mining what the First Century Lucius Junius Moderatus Columella did for agriculture in his "De Re Rustica" and adds that agriculture "is not separated into so many (branches) as this art of ours, nor can I teach the principles of this as easily as Columella did of that." His was the first work, in any language, specifically intended to be of aid in acquiring a knowledge of mineral industry techniques. It is one of the tragedies of literature that he chose, in the classical tradition, to write in Latin, which few people who had any interest in his subject matter could read, and it was later translated into German by one unfamiliar with mining who, instead of giving the correct mining terms, reproduced the Latin equivalents which Bauer had invented, thus nullifying much of the potential helpfulness of the book.

In addition to the need, already mentioned, to find out how the workers who were most successful did things there was also the circumstance that the production of metals, especially of gold and silver, was usually held to be a perquisite of the ruling sovereign, and even though the actual operations were conducted by skilled entrepreneurs they needed to be supervised in order to ensure that the full amount of "royalty" was duly paid. This might involve so thorough an understanding of the technology as to know whether the work was being done in the way that would yield the most profit. People who were not themselves mineral producers needed thorough knowledge of mineral technology.

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[1] References are at the end of the book, page 287.

A third factor was that although the natural sciences, especially chemistry, were mostly still in only a rudimentary stage of development they were tending to associate themselves with the institutions of classical learning, which not only had no facilities for promoting their application to solving the problems of everyday living, but were not in the least interested in the performing of such a function. In spite of this fact it seems justified to claim that the mineral industries were, during the early Middle Ages, enlisting the aid of the most highly developed technological knowledge. The modern steam engine owes its development to the efforts to utilize steam as a means of pumping water out of mines, for example.

A reason for this was that they were among the most profitable undertakings of the period. This was true especially at Freiberg in Saxony. The silver-bearing lead deposits there in the mountain range known as the Erzgebirge, between Saxony and Bohemia, had been discovered about the end of the twelfth century by carters who were hauling salt from Halle into Bohemia. They proved so much richer in silver than the similar ores of the Harz mountain district, which had been working since before the beginning of the tenth century, that a mining rush to the Erzgebirge took place. The outcome of this was, as Papperitz[43] has pointed out, that by the end of the sixteenth century it was the most highly developed mining district of Europe. It has already been noted that mining and metallurgy were the most highly developed of practical arts.

During this period people came from all over Europe to study operations in the Freiberg district, insofar as they were permitted to do so. Probably it was not the needs of these enquiring visitors, however, but the necessity to make some more systematic provision for the training of embryonic state officials that prompted Oberberghauptman Abraham Von Schonberg to propose to the authorities that they establish a system of free scholarships for natives of Saxony who would pledge themselves to enter the service of the state on graduation. This was carried out in 1702, Von Schonberg undertaking to arrange systematic instruction for the students and give it his personal attention.*

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* It is not clear when others were permitted to enroll on the payment of a fee. It is interesting to note that this pioneer in technical education in Germany was not, judging from his name, an "Aryan."

This first systematic instruction in mineral technology was not given in a classroom, but was rather like the training courses given to young men by some of our larger companies, except that those taken on had had no previous technical education. One suspects that they early found out the limitations of an operating plant as a place of instruction, for by 1712 there developed a movement to establish at Freiberg an "Augustus-Universität," in which assaying and metallurgy were to be taught as well as chemistry and physics. This heretical departure from the methods of medieval universities was evidently too radical, and the University of Leipzig, already 300 years old, was too near by for the proposal to win more than local support. Frederick Augustus, the Elector of Saxony, was probably also too much interested in developing his capital city of Dresden, only 20 miles distant, to be interested in spending money in Freiberg. Nothing more was done about it for 50 years.

Frederick Augustus had been King of Poland, as well as Elector of Saxony, since 1697, and he became the ally of Peter the Great of Russia in the Twenty-one Years War against Sweden. Peter was keenly interested in introducing European learning and technology into Russia. Whether he learned from Augustus what was being done at Freiberg we do not know, but at any rate he established, in 1709, a school in connection with the ironworks at Nevia. As far as the records indicate, this was only a primary school, but evidently it was intended to be one of the bottom rungs of an educational ladder in the technical field. Other schools were established elsewhere, and that started at Ekaterinburg in 1722 was later raised to high-school grade. In 1773 a School of Mines was established at St. Petersburg. (In 1896 the name of this was changed to Mining Institute of Catherine II.)

This, in plan at least, completed a system of graded education leading up to instruction in mining and metallurgy on a collegiate level in Russia. I have not been able to find any records indicating how well it functioned in early days, but the School at St. Petersburg eventually became a high-grade institution. Dimitri K. Chernoff (Tschernoff), who graduated from it in 1858 and taught there in various capacities until he became assistant manager of Aboucheff steelworks, was one of the world's great authorities on steel (he was made an honorary member of the

A.I.M.E. in 1902), and I am under the impression that his paper published in 1868, which was based on the thesis that steel is an iron-carbon alloy, was the first to present that view. The school also produced, and had associated with it, many other excellent technical men, but I can find no indication that many students from other lands attended it, or that mineral industry education in Russia had much effect on its development in other countries, possibly because the language offered so much difficulty.

The impulse toward providing for technical education for the mining industry started in Austria later than in Russia, but came to fruition sooner. The Empress Maria Theresa was Hungarian by birth and her interest in the industries of her native land brought about the issuance of an Imperial decree, dated June 13, 1763, ordering the establishment at Schemnitz, Hungary,* of a "bergschule." Gustav Faller has published[21] a history of this school. It began work with only one instructor, Nicholas Jaquin, and was not really well established before 1770. Though established as a mining school it very early became also a forestry school, and never attained the prominence of two schools in Austria, established later at Przibram and Leoben. It can, however, make a claim to be the first mining school, intended to be of collegiate grade, established in the world.

This is because the work at Freiberg was not put on a similar footing until 1765, when the then regent of Saxony, Prince Xaver, was persuaded to provide the funds for a building and hiring instructors. It began work on the new basis at Easter 1766, and two histories[21,23] of it have been published. Whether because of the reputation of the Freiberg district, or a wise educational policy, the instructing staff was composed from the beginning of men of high caliber, and for many years the professors of Freiberg were the outstanding men of Europe in mineralogy, geology, and the applications of chemistry and physics to mining technology. Everything considered, Freiberg seems entitled to the credit of having been the first real mining school.

In France, Perronnet, who was chief engineer of roads and ridges under Louis XIV, had started a school for draftsmen in is office, which was intended to be a training school for junior engineers. By 1775 this had so developed that it was regularly established as the École des Ponts et Chaussées, in which at first most of the instruction was given by the senior employees of Perronet's staff to their juniors.* The desire for increased government revenue from the mines of France caused Louis XVI to follow the suggestion of the mineralogist Balthazar G. Sage that he authorize the establishment of a school to teach mineralogy, assaying, and metallurgy at the Mint in Paris. In 1783 a Corps des Ingénieurs des Mines was established and the name École des Mines was given to the School. It was suppressed during the French Revolution, but in 1816 was reestablished in the Hôtel Vendôme, where it still remains.

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* Not to be confused with Chemnitz, Saxony, where Agricola was city physician from 1533 until his death in 1555.

No definite information on the history of mineral industry education in Italy seems to be available. Its city-states were regions of advanced culture in the Middle Ages and Tobias Dantzig relates[15] the story of the German father who in the fifteenth century was told that if his son wanted to study mathematics only through addition and subtraction he could do that in Germany, but if he wanted to master multiplication and division he would have to go to Italy to study. Agricola went there in 1524 for advanced study in medicine, the natural sciences, and philosophy; in the dedication of "De Re Metallica" he mentions that by reading Biringuccio's "de la Pirotechnia" (published at Venice in 1540), "I have refreshed my memory of those things I myself saw in Italy." The Hoovers say (p. 420, ref. 1), "It is our impression that the whole of this discussion on Iron in *De Re Metallica* is an abstract from Biringuccio, who wrote 15 years earlier, as it is in so nearly identical terms. Those interested will find a translation of Biringuccio's statement in regard to steel in Percy's 'Metallurgy of Iron and Steel,' London, 1864, p. 807." Biringuccio's main interest seems to have been in the manufacture of firearms. The general poverty of the Italian peninsula in mineral resources may indicate why, although an advanced knowledge of the natural sciences existed there, we find little bearing very directly on mineral industry education before the nineteenth century.

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* Perronnet is often referred to as "the father of engineering education," but, as shown above, technical education which included engineering had been initiated in Germany, Austria, and Russia before it began in France.

It is rather curious that little is also known of mineral industry education in Spain and its dominions.[31] Since that country controlled so large a part of world mineral production in the sixteenth, seventeenth and eighteenth centuries, one might expect it would be in the forefront of this field, but the reverse is true. I know of no such institution in Spain itself, and the general Spanish policy of merely utilizing the New World as a source of wealth instead of developing it, in the sense in which we use that word, resulted in little interest in education for the natives or the children of Spanish parents resident there.* And the weight of evidence seems to indicate that governmental supervision of mineral enterprise was usually lax and sometimes corrupt. Work in the mines was done by native laborers who knew how to do it in their own way; the supervision was that of a slave driver. The only school on which I can obtain definite information is that at Mexico City, which was not established until 1792, as a Real Seminario de Mineria. Its name was later changed to Colegio de Mineria; next to Escuela Nacional de Ingenieros. It is now the engineering faculty of the National University. A "practical" school of mines existed for a time at Zacatecas, and later at Pachuca.

Poland also makes a claim to have been early in this field. Of the mining school (*bergschule*) at Tarnowskie Gory, Poland, the director of the Unia Polskiego Przemyslu Gorniczo-Hutniczego at Kattowice says, in a recent letter, that "This very old institution—in fact, one of the oldest mining schools in the world—was created in 1581, and organized scientifically in 1803." I have no other information about this institution and it seems reasonable to conclude that it was, before 1800, only an ordinary school, with perhaps some attention to a local mining industry.

The Bergakademie, established at Berlin in 1799, is the only other mining school that seems to have been founded before 1800. At first it accepted only students who were training for state service in Prussia. There was a Latin school at Clausthal as early as 1774, but the mining work was not introduced till later.

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* Though the Spaniards founded twenty-five "universities" in America, they were scholastic and decadent, with little vitality except in churchly matters. Alvaro Alonso Barba, whose "El Arte de los Metales" was the first American work on mineral technology (1640), was a priest at Potosi, Bolivia.

In the 1860's its faculty were transferred to Berlin, but mining and metallurgical instruction also continued at Clausthal. The schools at Eisleben, Aachen, and Halle in Prussia, were developments of the nineteenth century, as were those of Leoben and Przibram in Austria. The mining school established at Falun, Sweden, was transferred to Stockholm in 1869. Though the University at Liége, in Belgium, had its beginning in 1811, its École des Arts et Manufactures et des Mines was not established until 1836. The school at St. Etienne, France, planned for during the French Revolution, was not actually started until 1816. I have not been able to find the date of beginning of that at Nancy, but apparently it was later.

Education for the mineral industry was slow in starting in Great Britain, and it was not until the Exhibition of 1851 in London awakened a demand for technical education that the "Government School of Mines and Science Applied to the Arts" was established in connection with the Geological Museum in Jermyn Street. The name was changed twice before it became the Royal School of Mines in 1863. The various steps that eventually led to its incorporation into the Imperial College of Science and Technology, University of London, as one of its constituent schools, are easily accessible in the annual calendar of the College, so need not be recorded here. Instruction in mining and metallurgy was gradually introduced into various other institutions in Great Britain, but none of them, except possibly the Royal School of Mines, seem to have had any appreciable influence on developments in the United States. R. H. Richards, in his address on mining schools,[55] mentions 15 mining schools in the United States but only the Royal School of Mines in England, while John A. Church, in his article on the same subject,[13] does not even mention that, though he discusses German, Austrian, and French schools at some length.

Before concluding this brief review of the beginnings of education for the mineral industries, it seems desirable to discuss the objectives and methods in more detail than was practicable in the historical summary. It will have been plain that the original main purpose was to train supervisory officials at the then highest technical levels. Schools which would prepare the students for this advanced instruction were necessary. It would require too much space to review the various systems that were tried, varying from the original Russian system, already described, to adjustments in the general educational system which would permit it to meet this need. In France, for example, students who have completed the instruction in the ordinary secondary schools take a special mathematical course, offered in a relatively few institutions, which is a preparation for the competitive entrance examinations of the three national mining schools.

In addition to providing for this advanced technical education it was also early recognized that beneficial effects might be expected from making some arrangement for the education of the ordinary mine workers. Whether this should be elementary general education or vocational education has been much debated. Vocational education essentially has as its objective the qualifying of a man to perform better the work he is doing; general education equips him for higher tasks and larger responsibilities. Seen in this way it is evident that there is a need for both, and also that general education should have more popular appeal than vocational education. The Bergschule in Germany were of two kinds, those where the instruction was primarily vocational and others where it was really technical. The one taught the workers to do things in the way they always had been done; the other qualified them to discover how to do them better. In general the Bergschule were not preparatory to the Bergakademie, but a single institution sometimes offered instruction on both levels. This basic problem of the relationship of vocational to technical education, which is still with us, is one that is familiar to all mineral industry educators (except possibly those who are interested only in mining education at the university level), and it seems unnecessary to enter on a discussion of the details of the various ways of meeting it that have been tried. Vocational mining education in the United States will be discussed at its proper place in a later chapter.

CHAPTER 2

AMERICAN BEGINNINGS

ALTHOUGH the first colonists in the area that is now the United States, whether Spanish, French or English in nationality, were usually keenly interested in the possibilities of mineral wealth, it is a curious and interesting fact that none of them happened upon the mineral deposits that eventually were to make this the greatest mineral-producing country; up to 1800 it would probably have been rated as rather poor in minerals. Spanish explorers traversed the southeastern United States without finding the Appalachian gold deposits that aroused so much interest in the early nineteenth century; Coronado sought in vain for the seven golden cities of Cibola; and the important gold deposits of California were not discovered until the political sovereignty of the region had passed from Mexico, which had held it for three centuries.

The French also held Canada for nearly two centuries (and the British for another century) without finding the mineral deposits in Ontario and Quebec that now are so important. Though they knew of the copper of the Keweenaw peninsula, the lead ores of Wisconsin and Missouri, and the coal of Illinois in the seventeenth century, these deposits were all too remote for exploitation. In the area held by Great Britain, iron smelting was planned at Jamestown as early as 1619 and was actually begun at Lynn, Mass., in 1643. The industry grew slowly, at first, but had reached considerable importance before the Revolution. Commercial bituminous coal mining began about 1750 in Virginia but anthracite mining in Pennsylvania was not started until 1800.

As a result there was naturally little interest in the technical aspects of mineral production here before 1800 by any except the few people who were actually engaged in it. Students of natural science were much interested in minerals, however. The activities of those who rank as geologists are so thoroughly covered in the collection of biographical sketches by George P. Merrill[35] as not to need further discussion, but it seems desirable to call attention to the persisting relationship between medicine and mineral technology. Agricola's interest in minerals had been a financial as well as an intellectual one, but various other physicians who early wrote on the subject of minerals had had their interest in them aroused by mineral *materia medica.* Druggists are still called chemists in England, because in the early days a person who had a good knowledge of *materia medica* usually also knew what was then understood about chemistry.

Among those in the United States whose names must be mentioned is Samuel Latham Mitchill, who had taken his M.D. degree at Edinburgh, and was appointed professor of chemistry, natural history, and philosophy at Columbia College in 1792. In 1797 he started, and thereafter edited, the "Medical Repository," in which, though it was primarily a medical journal, he published his first report as a "commissioner" on the geological conditions in eastern New York and in 1800 a report on the geology of Long Island. In 1799 he founded the American Mineralogical Society, of which he was president, and its prospectus urged "fellow-citizens" to transmit to the society information regarding, and specimens of, various minerals. An interesting note regarding "The Picture of New York; or a Traveller's Guide through the City of New York," which he wrote at the request of the City Hotel (which published it in 1807) is that it not only contained a long chapter on the geology of Manhattan island, but also inspired Washington Irving with the idea of writing a parody on it—his much better known "History of New York," ostensibly written by Diedrich Knickerbocker. Mitchill had meanwhile resigned his professorship, having been elected to the House of Representatives in 1801. In 1807 he became professor of chemistry and vice-president of the newly organized College of Physicians and Surgeons in New York. He contributed 110 pages of "observations on the geology of North America" to the English translation of Cuvier's "Essay on the Theory of the Earth," which was published in New York in 1818.

Adam Seybert took his M.D. at the Philadelphia Medical School in 1793, writing a graduation thesis that was remarkable for a youth of 20. He then went abroad for further medical study at London and Edinburgh, finally arriving at the École des Mines in Paris, where he studied chemistry and mineralogy. He was, so far as I can find, the first American student to study there. In August 1796, he was back in Philadelphia making experimental observations on the composition of air, and refers in his publication on them to experiments made at sea from June 26 to July 5 "during a passage from Bordeaux to Philadelphia." He therefore must have still been abroad when Wistar, in 1795, urged his appointment as professor of chemistry at the University of Pennsylvania. The appointment went to James Woodhouse instead but Seybert seems not to have minded, and gave the lectures for Woodhouse when the latter was ill. Seybert set up a shop as "chemist and mineralogist" at 168 N. Second St., Philadelphia. He made a catalogue of American minerals from various parts of the United States, which naturally was richest in those occurring in the vicinity of Philadelphia. In 1802, Benjamin Silliman, a student of law, was appointed professor of chemistry and natural science at Yale (though he knew nothing of either). He spent the winter of 1802–3 studying under Woodhouse at the University of Pennsylvania and in 1803 asked Seybert to name for him the few mineral specimens in the collection then at Yale. In 1806 Seybert noted the occurrence of zincblende near Perkiomen Creek, Montgomery County, Pennsylvania, and later engaged in a public controversy with James Woodhouse as to whether it could be used to produce zinc metal. Only one copy of the printed pamphlet containing "Woodhouse's reply to Seybert's strictures on his essay concerning the Perkiomen Zinc Mine," now in the library of the American Philosophical Society, seems to be in existence.

Seybert was a member of Congress in 1809–15 and again in 1817–18. He prepared the text for the "Statistical Annals of the U.S.A.," which was printed by Congress some time prior to December 1818, when a deficiency appropriation of $400 to cover its cost of printing was passed. This work, by the way, inspired Sydney Smith to write a satirical essay on the United States that is of much interest, but need not concern us here.

Henry Seybert was Adam Seybert's son; his mother died when he was small and his father apparently gave more attention to his upbringing than is usual. He, too, was sent to study at the

École des Mines in Paris. When he returned to America he took up the chemical analysis of minerals. As an example of his work, he published an analysis of a specimen of chrysoberyl that he collected at Haddam, Conn. in 1823. As his results differed from those of Klaproth and Berzelius, he analyzed a number of other specimens of chrysoberyl, his analytical methods being better than those previously used. In 1823 he pointed out the presence of magnesium in the cement used in the construction of the Erie Canal, which had been overlooked by previous analysts. He was elected a member of the American Philosophical Society when he was only 22 years old. He was long its president and is recorded as having given it 1000 pieces of chemical apparatus and 267 volumes on chemistry and physics. The Philadelphia Academy of Sciences bought a collection of minerals from Adam Seybert in 1814. In 1825 Adam Seybert died. All the evidence indicates that both Adam and Henry Seybert were rich men and after his father's death Henry seems to have been greatly concerned over the verse in the Bible which says that it is almost impossible for a rich man to enter Heaven; so much so that he made a trip to France to consult the Bishop of Rouen about it. Though Henry lived until 1883, he seems to have taken but little interest in scientific work after his father's death, and in 1883 he gave to the University of Pennsylvania $60,000 worth of bonds to establish the "Adam Seybert Chair of Moral and Intellectual Philosophy," with instructions that the incumbent was to "make a thorough and important investigation of all systems of morals, religion or philosophy which assume to represent the truth, and particularly of modern spiritualism." The residue of his estate was used to establish a charitable foundation, which is still active.

So much space has been devoted to the Seyberts because they are both overlooked in G. P. Merrill's "The First Hundred Years of American Geology."[35] An even more important point is that they were both intellectually qualified to make important contributions to the application of science to the mineral industry in America but through the accidental circumstance of being wealthy had no incentive to do more regarding it than they found congenial. They were qualified to have become outstanding pioneers in the application of science to the problems of the mineral industry, but now even the contributions they did make are almost forgotten.

It will not be necessary to discuss at length the development of geological knowledge in the United States, since it is treated in so much detail by Merrill,[35] but for the convenience of the reader it should be pointed out that although mineralogy is a very old subject, Theophrastus (371–288 B.C.) having described some 16 distinct species of minerals in his work on stones, and later writers continually adding to the number, there was no important work on the nature of ore deposits before the publications of Agricola (George Bauer) in the sixteenth century and so little subsequent progress that the ideas of Werner,* published in 1791, are a regression instead of an advance on those of Agricola. Amos Eaton gives 1820 as the close of the first era in American geology, and Merrill calls this the Maclurean era because of the contributions by William Maclure (a Scot who took up geology after having made a success in business) to knowledge of areal geology in this country. The decade 1820–1830 Merrill calls the Eatonian era because of Amos Eaton's work in New York state, under the patronage of Stephen van Rensselaer. We shall have occasion to refer again to Eaton.

The decade 1830–1840 is of extreme interest because it includes the establishment of a State Geological Survey in Massachusetts in 1830; in Tennessee and Maryland in 1831; in New Jersey, Connecticut and Virginia in 1835; in Maine, New York, Ohio, and Pennsylvania in 1836; in Delaware, Indiana, and Michigan in 1837; and in New Hampshire and Rhode Island in 1839. Details regarding these can be found in *Bulletin* 109 of the U. S. National Museum (1920) and we cannot linger over them here other than to make the point that they are concrete evidence of the recognition of the idea that the scientific study of natural resources of a state is a proper function of its government. In addition to the State surveys, three were undertaken by the Federal Government in this period, and two more in the succeeding 10 years (1840–1850) when Alabama, South Carolina and Vermont were also added to the list of State surveys.

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* See historical note on the theory of ore deposits in H. C. and L. H. Hoover's translation[1] of De Re Metallica, pp. 43–53. Mr. Hoover says of Werner that "he halted the march of advance of thought on these subjects by half a century."

In 1850–1860 California, Illinois, Iowa, Kentucky, Mississippi, Missouri, Texas and Wisconsin established state geological surveys, while six states that had made a previous start now made a second one. The Federal Government was particularly interested in surveys in connection with proposed Pacific railways, and there were other exploring surveys to which geologists were attached. These geological surveys were not only adding to the store of factual knowledge regarding mineral deposits in America, but were furnishing a field for the application of geological and mineralogical knowledge, and were serving as training schools as well for the assistants of the geologists in charge.

While this growing interest in the economic aspects of geology caused more attention to be given to that subject in the existing schools and colleges, the credit for furnishing the impulse that led to the establishment of engineering education in the United States is given by C. R. Mann[32] to the needs of agriculture: "By 1812 the exhaustion of the soil by unscientific methods of agriculture was already driving the population to seek new land in the West." State legislatures were being petitioned to do something for agriculture, and a report of the Committee on Agriculture to the legislature of New York in 1823 urged the establishment of a tax-supported agricultural school like that at Hofwyl, Switzerland. A detailed plan for the school was submitted and Stephen van Rensselaer was prepared to give the land necessary for the project, but the legislature refused to adopt it. Van Rensselaer, undiscouraged, went ahead in 1824 to establish a Rensselaer School at Troy, "for the purpose of instructing persons who may choose to apply themselves in the application of science to the common purpose of life. My principal object is to qualify teachers for instructing the sons and daughters of farmers and mechanics, by lecture or otherwise, in the application of experimental chemistry, philosophy, and natural history to agriculture, domestic economy, the arts and manufactures." It will be noticed that this was intended to be a teacher's college. Amos Eaton, who had just completed a geological and agricultural survey of Rensselaer County, was assigned the task of creating the school, and the course given there in 1824 was one year in length. The first term was spent in collecting botanical, mineralogical, and zoological specimens and in visiting shops and factories. In the winter the class reviewed the sciences they had been covering in the autumn, in addition to studying rhetoric, logic, geography, and mathematics. Part of the spring term was devoted to lectures, which the students themselves were required to give, on "experimental philosophy," chemistry, minerals, soils, and mineral waters, and the rest of it to study, in the school and in the field, of actual enterprises.

As we shall see later, a school develops according to its original plan only when that plan is in close accord with the actual needs of the time and place, and when there are no local forces that act against it. The men who built the Erie Canal were self-taught engineers, and that undertaking may serve as an example of the many that, in the first half of the nineteenth century, were calling for the services of men able to handle projects involving engineering. It is not surprising, therefore, to find the course at Rensselaer in 1825 containing instruction in land surveying, mensuration, measurements of the flow of water in rivers and aqueducts[65] and the next year in hydrostatics and hydrodynamics. The words "civil engineering" first appear in the catalogue for 1828 and the degree of Civil Engineer was first given in 1835, for a one-year course. The teacher-training idea seems by that time to have been definitely dropped. It was the first, and long the leading engineering school in the United States.

Three other schools must also be mentioned. The Military Academy at West Point had been reorganized in 1817 by Colonel Thayer,* who had made a study of European schools. While the subjects taught there were considered from the military viewpoint they had enough general bearing so that graduates of the Academy in this period, turning to civil life because of apparent lack of opportunity in a military career, played an important part in engineering development, especially of the early railroads.

Harvard had long been interested in natural science. President Hoar wrote to Boyle, as early as 1672, "and a laboratory chemical for those philosophers that, by themselves, would culture their understandings, are in our design for the students to spend their times of recreation in." (Evidently Harvard did not then teach the rule that "a preposition is not a proper word to end a sentence with.") Though a professor of mathematics and natural philosophy was appointed in 1727 the first "laboratory chemical" was provided in 1783, with the appointment of a professor of chemistry in that year. Benjamin, Count Rumford, bequeathed £1,000 to Harvard in 1814, for a professorship to teach "the utility of the physical and mathematical sciences for the improvement of the useful arts, and for the extension of the industry, prosperity, happiness and well-being of society"; this was used for instruction in chemistry.

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* After he retired from the Army, in 1867, he endowed the School of Engineering, which bears his name, at his alma mater, Dartmouth.

In 1847 Abbott Lawrence gave $50,000 to Harvard to endow professorships in geology and civil engineering. Though the terms of the letter conveying the gift specified "mining in its extended sense, including metallurgy" as one of the "three great practical branches to which a scientific education is to be applied," the Scientific School of the University, which had been created by vote of the Corporation a few months earlier, was at once renamed the Lawrence Scientific School. Though it was intended to give "systematic instruction in those branches of science which are immediately connected with the industrial interests of the country, such as chemistry in its various applications to the arts of life; . . . " the men appointed turned it into a school of pure science. Louis Agassiz was appointed professor of zoology and geology, but though he continued to lecture on geology until 1875 his main interest was in zoology as a pure science. Half of the Lawrence gift was spent for a new building and the remainder kept as endowment for professorships in geology and engineering. E. N. Horsford, who had just been appointed Rumford Professor of the Application of Science to the Useful Arts, was transferred to the new school, and in 1849 H. L. Eustis, who had been assistant professor of civil engineering at West Point, was made professor of engineering. The degree of Bachelor of Science was given, but no curricula were offered; it was rather a tutorial system under which a student could take so much of instruction as a professor offered. The early catalogues show Eustis as giving instruction in descriptive geometry, with its application to stonecutting and mapping, surveying, both theoretical and practical; and the nature and properties of building materials and their application to the construction of railroads, canals, bridges, etc. Apparently his students spent the whole day with him. Not many students came to the School and the curious outcome of all the forces acting on it was that, although "no department of the University, or, it is probably safe to say, of any University in America has graduated so large a proportion of men who reached high distinction in later life," it steadily declined in the next 20 years to "not much more than an annex to the College, which harbored students whose desire for the cheer and good-fellowship of college life surpassed their intellectual zeal or capacity." Abbott Lawrence gave the School another $50,000 in 1859 and his son James gave it $50,000 more in 1865.

The third school was Yale. It has been mentioned that Benjamin Silliman, then a law student, had been appointed professor of chemistry and natural philosophy there in 1802. First acquiring what was for those days a competent knowledge of those subjects, he proceeded to teach them with vigor and enthusiasm, especially geology and mineralogy. In 1806 he prepared a sketch of the geology about New Haven, which was published in the Memoirs of the Connecticut Academy of Sciences in 1810; in 1818 he started *Silliman's Journal* (which under the changed title of the *American Journal of Science* is still published), and in 1829 he edited an American edition of Bakewell's "Introduction to Geology." In 1830 he published a two-volume "Elements of Chemistry." There were no facilities for chemical laboratory instruction until 1842, when Benjamin Silliman, Jr., who had graduated at Yale in 1837 and become his father's assistant in teaching chemistry and mineralogy and in editing the *American Journal of Science,* secured a room, which was fitted up, and "here, as a purely private enterprise, he received a few students for practical instruction in chemistry and in mineralogy, students who were not enrolled in the college, and not considered as members of the institution."[11]

The story of how, from this beginning, there was created at Yale, in 1847, a Department of Philosophy and Arts, with official recognition that the School of Applied Chemistry (in which J. P. Norton was professor of agricultural chemistry and Benjamin Silliman, Jr., was professor of practical chemistry) was a part of Yale is told in detail in the work cited, and need not be repeated here. Norton and Silliman rented a building and raised privately the means to equip it. They carried on the School at their own risk until Silliman left to teach chemistry in the Medical School of the University of Louisville in 1849; Norton carried on alone until he died in 1852, two months after the Corporation had authorized the granting of the Bachelor of Philosophy degree to students who had completed a two-year course and passed specified examinations. J. A. Porter, who had studied under Liebig, had been Horsford's assistant at Harvard, and for two years had taught "chemistry as applied to the arts" at Brown, was brought in to take Norton's place. At the same time J. A. Norton, a graduate of West Point in 1831, who had been teaching civil engineering at Brown for two years, was also brought to Yale as professor of civil engineering. Norton's class at Brown came along with him, and Yale in 1852–53 had 26 students of civil engineering and 25 in applied chemistry; 16 of the total already had either bachelor's or master's degrees. In 1854–55, these two groups (applied chemistry and civil engineering) were designated the "Yale Scientific School." The events following the appointment of a professor of metallurgy in this school are described on p. 24.

CHAPTER 3

MINERAL INDUSTRY EDUCATION IN THE UNITED STATES

SUGGESTIONS that existing schools give instruction bearing on the mineral industry, or that schools for that purpose should be established in the United States, began to be made early, and it would require too much space to catalogue them all. Some of the more important may be mentioned to indicate their general character.

In the "advertisement to such parents as have now (or expect to have) children prepared to be educated in the College of New York," which appeared in the New York *Mercury* of June 3, 1754, Samuel Johnson, the first president of King's College, the predecessor of Columbia, said that it was the "design of this college to instruct and perfect the youth," among other things, "in the arts of Numbering and Measuring of Surveying, and Navigation and Geography. . . . and in the Air, Water and Earth around us, and the various kinds of Meteors, Stones, Mines and Minerals, Plants and Animals; and in the knowledge of all Nature in the Heavens above us, and of everything useful for the Comfort, Convenience and the Elegance of Life . . . " Though the concept that natural science should be used to enlarge the bounds of human life was thus implicit at Columbia from the very beginning (John Stevens graduated from it in 1768, James Renwick in 1807, Horatio Allen in 1823, and A. W. Craven in 1829), it was only during the period of Renwick's professorship of Natural and Experimental Philosophy and Chemistry (1820–1853) that much attention was given to applied science.*

Among the Austin papers, published by the American Historical Association,[2] there is a draft in Stephen F. Austin's handwriting of a proposed memorial from the legislature of Missouri to Congress, not only urging "the propriety and utility of promoting the manufacture of crude lead at the several lead mines in the United States by laying an additional duty on the importation of that article," but also saying:

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* See chapter 4 for early interest in this subject in Philadelphia.

> And your Memorialists further represent that in consequence of there having been as yet no appropriation of Public Lands in this Territory for the use of Schools there are no Academical Institutions in the Country whence evils are dayly resulting which are in the highest degree pernicious and indeed ruinous to the harmony and morals of society, and obnoxious to the vital principles of Republicanism which eminating from enlightened Reason have everything to dread from the ignorance of the people. Congress are therefore most respectfully and earnestly solicited to devote an early attention to such measures as will tend to promote the diffusion of useful knowledge in this Territory and for that purpose to appropriate at this time and until further provisions are made, So much of the Revenue arising from the Public Lead Mines as may be deemed sufficient for the establishment and support of an Academy at the Town of   in the County of   in this Territory which is recommended as a situation combining all the advantages of locality, Healthiness and Economy so essential for such an establishment.

There is no proof that this memorial was ever adopted by the legislature and transmitted to Congress nor record of its precise date, which must have been about 1817 or 1818. That Austin may have had in mind a mining school is suggested by the next paragraph.

In the opening chapter of his book[58] on the lead mines of Missouri, published in 1819, Schoolcraft said:

> The acquisition of a scientific knowledge of minerals should also be facilitated by the establishment of a seminary in this quarter. There should be a mineralogical school located in the mine country, where students might be instructed in that useful science. In a country so rich in minerals and fossils, and whose wealth will always so much depend upon a proper development of these resources, the knowledge of minerals should be laid open to everyone, and it should be within the reach of such as do not wish, or cannot get the other branches of a liberal education. To obtain this knowledge now, even were there a prevelent taste for it, a person would be compelled to travel to remote parts of the union, and to incur an unreasonable expense. No one who is conversant with the advantages which various parts of Germany, and particularly Saxony, has derived from such a seminary, will deny the utility of a similar one in the United States; and as to its location there can be no question, for, compared with any other section of the union, this will be found the land of ores—the country of minerals.

The letter accompanying Abbott Lawrence's gift of $50,000 to Harvard in 1847, to endow professorships in geology and civil engineering, said: "The three great practical branches to which a scientific education is to be applied are: first, engineering; second, mining in its extended sense, including metallurgy; third, the inventions and manufacturing of machinery." Development was not to follow this original lead.* A less congenial atmosphere for the development of applied science than existed in the Harvard of 1847 is not easily imagined, while the two professors first appointed, Louis Agassiz, professor of zoology and geology, and Eben Horsford, Rumford Professor of the application of science to the useful arts, were interested in the pure-science aspects of biology and chemistry. So the school developed into one of pure science. W. B. Rogers, who was later to found the Massachusetts Institute of Technology, and who already was discussing it with his brother Henry (who had originally suggested it in 1846), wrote to Henry on Oct. 3, 1847 as follows:

> . . . The more I think of our plan of a Polytechnic School, the more confident I feel of its rapid and great success. The Lawrence School never can succeed on its present plan in accomplishment of what was intended. It can only, as now organized, draw a small number of the body of students aside from the usual college routine. It should be *in reality* a school of *applied science*, embracing at least four professorships, and it ought to be in a great measure independent of the other departments of Harvard. Besides, Cambridge is not the place for such a School. It should be in *Boston.*

Rogers' views were sound, and although Abbott Lawrence gave the school another $50,000 in 1859 and his son James $50,000 more in 1865, no mining instruction was offered at Harvard till 1866. Then, as we shall see later, it was really economic geology, and not mining, that was taught.

How there gradually developed a Department of Philosophy and Arts and eventually the Yale Scientific School† in 1854–55, from Benjamin Silliman's appointment as professor of chemistry and natural philosophy at Yale in 1802, has already been related. What is of greater significance for us is that the Corporation on July 24, 1855, voted to establish a new professorship in the

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* The Harvard catalogue for 1847–48 indicates that plans had been formulated the year before for "an advanced School of Science and Literature," a graduate school in "the various branches of exact and physical sciences and classical learning." After Lawrence made his gift it was designated as the Lawrence Scientific School.

† Later renamed the Sheffield Scientific School.

Department of Philosophy and the Arts, "to be called the Professorship of Metallurgy." So far as I can find out, this was the first professorship of metallurgy established in the United States. George J. Brush was appointed to the chair.

George Brush was the son of a Brooklyn, N. Y., commission merchant and became interested in mineralogy and natural science in the private school he attended until he was 16 or 17. He then took a business position, but as it did not seem to agree with his health he decided to try farming, and as a proper preparation for the latter went to Yale to study agricultural chemistry. He worked for a year under the younger Silliman, who later called him down to Louisville Medical College as his assistant after he had been there one year himself. He made a trip to Europe in the company of the senior Silliman and at the Yale commencement of 1852 was one of the six men who were the first to receive the Ph.B. degree there. He then became J. Lawrence Smith's assistant at the University of Virginia. The summer of 1853 he spent as assistant in the mineralogy department of the Crystal Palace Exposition in New York, and in the autumn he went to Germany to continue his studies under Liebig, von Kobell, and Pettenkofer, eventually arriving at the Bergakademie at Freiberg. While there, he received the Yale appointment, which, we may infer, was brought about by Benjamin Silliman, Sr.

Instead of taking up his post at Yale immediately he spent the winter of 1855–56 at the Metropolitan School of Science Applied to Mining and the Arts (as the Royal School of Mines in London was then known), studying under Dr. John Percy, a physician who had turned from medicine to metallurgy and was not only the most distinguished metallurgist of his time but one of the great metallurgists of all time. At the end of the spring session in 1856, Brush began visiting all the important metallurgical establishments in England and on the Continent to which he could obtain access, and when he returned to New Haven, in January 1857, to take up his duties as professor of metallurgy, he had both theoretical and practical knowledge of it.

At the risk of seeming flippant, I cannot forbear comparing Professor Brush to a young lady who was invited to bring her harp to a party, but was not asked to play. Brush was, next to Percy himself, the man in the English-speaking world of 1857 best qualified to teach metallurgy, but there was then no opportunity to teach it at Yale. Ironmaking, our only important metallurgical industry at the time, was still an empirical art; it was not until some years later that it was generally admitted that even an analytical chemist was worth his keep at a blast furnace or steel plant. The metallurgy of nonferrous metals, as pointed out in the preceding chapter, was to have need in the near future for competent technologists, but when that need developed it was mostly met by German metallurgists who had emigrated to America (many of them as a result of the political outbreak of 1848). Frederick Overman, one of the best iron metallurgists of Germany, had come to America in 1842, but found so little opportunity for employment here, even after he opened an analytical laboratory in Philadelphia, that he had to turn to the writing of metallurgical works in English in order to make a living. His 500-page "Manufacture of Iron" (1849), his 225-page "Manufacture of Steel" (1851) and the 700-page "Treatise on Metallurgy," which was published after his death, in 1852, were for a long time the best American works on those subjects. The reason for mentioning him here is to make clear the point that there was in 1850–1860 little or no opportunity for employment for an academically trained metallurgist in the United States.

Chittenden's history of the Sheffield Scientific School records Brush as giving some public lectures on iron metallurgy in New Haven, but I cannot find that he ever had any real opportunity to teach metallurgy in the school. It was not a required subject in either the curriculum in chemistry or that of civil engineering, and virtually all the students of the time were taking one or the other. But mineralogy was required in both. James D. Dana, professor of natural history, was then in charge of the courses of mineralogy, and Brush, whose original interest had been in mineralogy, and who was as well qualified to teach it as he was to teach metallurgy, turned his attention to it as well as to administrative work.* In 1864 his title was changed to professor of mineralogy and metallurgy, and in 1871 to simply professor of mineralogy, O. D. Allen having been appointed professor of metallurgy and assaying. Allen was more of a chemist than a metallurgist; two years later his title was changed to professor of analytical chemistry and metallurgy, and thereafter he seems to have given practically all his time to analytical chemistry. When he resigned in 1887 there seems to have been no appointment in metallurgy.

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* He was secretary of the faculty and treasurer of the School.

So much space has been given to outlining the consequences of the appointment of Brush as professor of metallurgy at Yale in 1855 because it illustrates that it is easy to give too complete credence to the often-quoted dictum that if you can make a better mousetrap than any one else the world will beat a path to your door. That saying assumes that the world feels an urgent need for better mousetraps; if it does not, you might produce a perfect mousetrap and no one but yourself would have any interest in your ability. In 1857 Brush was the best-qualified man in the United States to teach metallurgy,* but he had so little opportunity to exercise his ability that it gradually atrophied. Yale, which in 1857 was in a position to become the outstanding institution in the United States at which to study metallurgy, had to make a fresh start 50 years later, as will appear in due course. With the assertion that more than the provision of a competent teacher is necessary for the successful development of a course in any field of knowledge, we must proceed to consider other elements involved in the development of technical education for mineral industry in the period 1800–1860.

An important one of these was the interest of young men in acquiring technical education to fit them for success in working in the mineral industry. What has been said will perhaps be interpreted by some to indicate that there was no interest among American students in the subject of metallurgy, or, by inference, in mining. Such an assumption is not warranted by the known facts. Granted that Adam Seybert and his son Henry went to Europe to study in the École des Mines mainly because of their interest in the chemistry of minerals, and some at least among the many American students who later went to Freiberg to study at the Bergakademie may also have been principally interested in mineralogy and geology, their subsequent careers indicate that there was in the United States prior to 1860 no little interest among students in the application of scientific education to "min-

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* Frederick Overman had been killed by gas poisoning in his own laboratory in 1852.

Name	Residence	Year of Entrance
Wm. H. Keating	Philadelphia	1819
Theodore F. Moss	Philadelphia	1838
William L. Faber		1846
Henry Rohdewald	Baltimore	1849
Franz Lennig	Philadelphia	1849
Eugene Hilgard	Illinois	1850
John G. Ellery	New York State	1851
William Bradley		1852
William Ketchell	New Jersey	1852
John Blandy	New York	1853
John D. Eastor	Baltimore	1853
George Brush	Brooklyn	1854
James Hague	Albany	1856
Raphael Pumpelly	New York	1856
Leopold Bierwirth	New York	1857
Karl Froebel	New York	1857
Louis Janin	New Orleans	1857
Henry Janin	New Orleans	1857
William A. Kobbe	New York	1857
Rudolph E. Werthemann	San Francisco	1857
Lewis Falkenau	New York	1858
Alfred P. Rockwell		1858
John H. Boalt	Ohio	1859
S. M. Crafts	Boston	1859
Robert H. Lamborn	Philadelphia	1859
Ernest Moss	New Orleans	1859
Francis Washburn	Boston	1859
John F. Lewis	South Carolina	1860
Rossiter W. Raymond	Cincinnati	1860
Augustus Steitz	St. Louis	1860
Louis Vogel	St. Louis	1860
Walter Crafts		1861
Edward H. Jackson		1861
Winfield S. Keyes	New York	1861
Benjamin S. Lyman	Massachusetts	1861
Eugene N. Riotte		1861
James B. Smith		1861
Eckley B. Coxe	Philadelphia	1862
William S. Lee	New Jersey	1862
William N. Symington		1862
Charles J. Duval	New Orleans	1863
Louis F. Reichert	California	1863
Augustus J. Bowie	California	1864
George L. Bradley		1864
Howard Crittenden	California	1864
Walter L. Kane		1864
Samuel F. Emmons	Boston	1864
Marshall Hastings	California	1864
Maximilian Koester	California	1864
Ethelbert Watts	Philadelphia	1864
John H. Caswell	New York	1864
J. W. Cortlan		1864
William M. Curtis	New York	1864
Thomas M. Drown	Philadelphia	1864
William B. Foster	Pennsylvania	1865
Robert Hazen	San Francisco	1865
Arnold Hague	Boston	1865
Almon D. Hodges		1865
Edward R. Howe		1865
Alexis Janin	New Orleans	1865
Richard J. Inge	California	1865
George J. Johnson		1865
Lebeus H. Mitchell	Massachusetts	1865
O. A. Moses		1865
Lyman Nichols	Boston	1865
Philip Oettinger	New York	1865
John B. Pearse	Philadelphia	1865
Edward D. Peters	Boston	1865
William H. Pettee		1865
Frederick Prime	New York	1865
Thomas C. Raymond		1865
Charles C. Rueger	California	1865
Duncan D. Templeton	New Orleans	1865
Sydney W. Tyler	Connecticut	1865
Gardner F. Williams		1865

ing in its extended sense," as Abbott Lawrence had expressed it in 1847, even though our schools had not yet found the way to provide exactly what was wanted. It will be of interest to list (p. 27) the students from the United States who studied at Freiberg prior to 1865.[23]

Though an American (p. 13) went to the École des Mines to study a quarter-century before any went to Freiberg, the total number who attended there is much smaller than the number at the German institution. The following list, covering the period 1850–1890, has been furnished by its Director:

Name	Residence	Years of Attendance
William Ashburner	Pennsylvania	1851–1854
Charles Pierre de Lassus	New Orleans	1853–1856
Charles Frederick Wadsworth	Genesee	1854–1859
Joseph Lesley	Pennsylvania	1856–1857
Thomas Egleston	New York	1856–1860
Emile Leon Soulie	New Orleans	1857–1860
Francis Vinton	Portland, Me.	1857–1860
Benjamin S. Lyman	Northampton	1859–1861
Eckley B. Coxe	Philadelphia	1860–1862
Samuel Franklin Emmons	Boston	1862–1864
Edward H. Jackson	Plymouth	1864–1865
Benjamin M. Pierce	Cambridge	1865–1867
Benjamin Frazier	Philadelphia	1866–1868
Daniel Callahan	New Orleans	1866–1868
Lowber Smith	New York	1867–1869
William Lucien Scaife	Pittsburgh	1876–1877
Frank Lyman	Brooklyn	1879–
Fereol Monnot	New York	1884–1887
Richard Perez	New York	1887–1890

If we plot these students in a curve, it at once becomes evident that before 1849 only a sporadic student went from the United States to study at Freiberg, between 1850 and 1853 there was a persistent but fluctuating group of 2 to 6 yearly, and that in 1864 the curve turned sharply upward, with 12 in that year and 21 in 1865. (The curve drops sharply after 1865 and only four American students entered Freiberg in 1870. In 1870–1880 there were usually 5 to 8 entering yearly.) Evidently 1864 was a critical year in the history of mineral industry education in the United States. Consideration of why that was true must needs be postponed until another element in the situation, the relation between our Federal Government and education, has been discussed.

As everyone knows, one of the first thoughts of the American colonists was to make due provision for education. The financial support of this was typically local, though the few institutions of secondary and higher grade properly looked for support to a region as wide as that which furnished their students. The Declaration of Independence, in 1776, and the subsequent organization of a Continental Congress gave rise to a public land problem that had educational aspects. The geographical boundaries of the colonies, thus united, were vague. New York claimed all the land that had belonged to the Iroquois Indians, while the charters of some of the other colonies said that they extended to "the South Seas," a phrase that was said to mean the Mississippi River. But New Hampshire, Vermont, Rhode Island, New Jersey, Pennsylvania, Delaware and Maryland not only had no claim to vague areas to the west of them but were not willing to see the other colonies so greatly expanded as they might be. New York took the lead in ceding its claim to the central government in 1780, and by 1785 a public land policy had been sufficiently formulated so that Congress was able to pass in that year an act providing for subdivision of the public lands into townships composed of 36 mile-square sections each, of which the sixteenth was to be set aside for school purposes. In 1787 an "ordinance" was passed, in more precise terms, also providing that not more than two full townships in each state should be set aside for a university.

This at once gave rise to the question as to whether the Federal Government retained any control over these lands, but it was decided that their control was vested in the state legislature. Saline lands were granted to Ohio in 1802 and after 1820 it became standard practice to grant two full townships of saline lands to a state on admission. Shortly thereafter the prospect of a surplus of funds accruing in the Federal treasury from the sale of public lands began to cause concern and it was proposed to distribute it, if and when it occurred, to the states for educational purposes. President Jackson eventually vetoed such a measure on the ground that Congress had no constitutional authority to vote Federal funds "for objects of a local character within the states."

Meanwhile there was also influential opinion that the Federal Government should establish and maintain a national university. George Washington evidently had it in mind when, in his Farewell Address, he urged the promotion of "institutions for the general diffusion of knowledge," since in his will he left a bequest of $25,000 to establish a national university at the seat of government.* Jefferson advocated the creation of a central academy at the national capitol, but seems to have visioned something more like the National Academy of Sciences rather than an ordinary educational institution. The idea of a national university at Washington has been much discussed ever since but has never been brought to fruition.

The situation was further complicated in 1826, by the action of James Smithson, an Englishman, who bequeathed his whole fortune to the United States to found an institution for "the increase and diffusion of knowledge among men." It was not until 1846 that the Smithsonian Institution, as we now know it, was established by Federal legislation, choosing for its field the support of research and exploration, the maintenance of museum collections, and the publication of scientific monographs, reports, and papers. In general, the Smithsonian has used its resources on projects that seemed worth while and for which no other support seemed likely to be available. Some of the best early work on electricity was done there, but it withdrew from the field when it became evident that other agencies could be relied upon to develop that field. It pursued the same general course in regard to aviation, but continues its work in ethnology and divides the field of geology with the U. S. Geological Survey, the latter carrying on exploration, mapping and research while the Smithsonian maintains the National Museum, which is especially rich in geological and paleontological material.

In the meanwhile an act had been passed, in 1836, to distribute surplus revenue among the states. Only three payments were made, because of the financial crisis that came soon after, but an act in 1841 granted 500,000 acres of public land to each state admitted after 1800. A more detailed discussion of this legislation, and of the attitude of the Federal Government toward

* Congress had voted him 40,000 acres of western land for his military services.

education, can be found in *Bulletin* 10 of the Carnegie Foundation for the Advancement of Teaching, by I. L. Kandel.[30]

The most important action of Congress, from the educational standpoint, was what is popularly known as the Morrill Land Grant Act of 1862. A detailed discussion of this can be found in the publication just cited and in William Belmont Parker's biography of Justin Smith Morrill.[44] It will be remembered that C. R. Mann considers that it was the needs of agriculture that led to the establishment in 1821 of what became the first engineering school in the United States. From societies and individuals there had been, between 1824 and 1860, an unending succession of resolutions, memorials, and reports, to state legislatures and to Congress, urging that something be done to promote education in agriculture and the mechanic arts. One argument used in a report made to the Illinois Legislature in 1852 was that one-third to one-half of the products of the state were sacrificed annually because of the workers' ignorance of scientific laws and methods of work. (Possibly they had in mind the coal left in the ground by the system of mining used. This was not altogether due to ignorance, since an engineering study made 70 years later classed 15 to 25 per cent of the coal as necessary to be left behind in even the most advanced system of mining.) It was argued that such losses might be prevented if an "industrial university" would provide for the "industrial classes a thorough scientific and practical training . . . "

Senator Morrill always claimed that he could not remember where or how he first got the idea of Federal aid for vocational education, but that when he took up the idea of "doing something for the farmer" he found many men in many places had long been thinking along the same general line. Apparently, as a capable politician, he put through legislation which he thought he could secure, rather than fighting for any educational ideal, since he had but little contact with education. The history of the legislation can be most conveniently found in the Carnegie Foundation report cited above.[30] It will be enough to say here that he introduced his first bill in 1857 and without much difficulty got it through the House, of which he was then a member.

In the Senate the bill met with strong opposition on a variety of grounds but perhaps chiefly on the issue of States' rights, and it was not until February 1859 that it was finally pushed through the Senate. President Buchanan promptly vetoed it, in a message which made six points against it, of which the sixth was that it was unconstitutional. The attempt to repass it over the President's veto failed.

Undaunted, Mr. Morrill introduced a similar bill in December 1861. The debates in the House and Senate on this bill are interesting, but must not detain us here. It finally passed the Senate, after some amendment, and was signed by President Lincoln on July 2, 1862. It provided that each state should receive 20,000 acres of public land for each senator and representative, on the census of 1860. Apparently the states were expected to sell the land (and most of them did), but they were required to expend not more than 1/10 of the proceeds on buildings and equipment, and must keep the remaining 9/10 in a perpetual fund for the maintenance of instruction in agriculture and the mechanic arts. The supplementary legislation that was under consideration from 1872 until 1890 need not concern us here because we are interested in mineral industry, not agricultural education except insofar as it has a bearing on the general subject. Many of these "land-grant" colleges eventually provided instruction in mining and metallurgy, as will be seen in later chapters.

CHAPTER 4

UNSUCCESSFUL VENTURES

THROUGHOUT the Colonial era, Philadelphia was easily the leading city of North America, and it still held that position at the end of the period, with a population of about 25,000, though closely pressed by Boston, which had slightly over 20,000, and New York, which had nearly as many. It was the center of a region in which mineral industry was important. Thomas Rutter's bloomery, built in the Schuylkill valley in 1716, was quickly followed by many others, and during the Colonial period at least 20 blast furnaces, 45 forges, and iron-works of other types were built in eastern Pennsylvania, which easily led all the other colonies in iron manufacture. During the Revolutionary period others were erected as far west as Fort Loudon, in the Cumberland valley.[6] After 1800 the rapid development of the anthracite mining industry profoundly affected Philadelphia's development, since transportation of the coal was then necessarily by water, and the streams of the anthracite regions mostly flowed into either the Schuylkill or the Delaware Rivers. With an abundant near-by supply of coal and iron, with the seat of government, which had been there since 1774, and with a National Bank established there in 1791, one would have seemed safe in prophesying, at the beginning of the nineteenth century, that Philadelphia would permanently remain the leading city of the United States.

Education in Philadelphia was at first wholly in the hands of the Quakers, who had established a "Public School" there in 1689, but in November 1739 George Whitefield, who had created a sensation in England by his preaching, though only 24 years old, passed through Philadelphia on his way to Georgia to found an orphan school there. He preached a series of sermons in Christ Church that were so disturbing to the established church that on Nov. 25 the Rev. Richard Peters (who was also Provincial

Secretary) stood up in the middle of the service and controverted his doctrines. Benjamin Franklin was on Whitefield's side and after the latter was forbidden to preach in Episcopal churches, early in 1740, was a vigorous supporter of a movement to construct a building 100 ft. long and 70 broad "expressly for the use of any preacher of any religious persuasion, who might desire to say something to the people of Philadelphia." Perhaps it was Franklin's sense of thrift that proposed to have it serve also on week days as a "Charity School for the Instruction of Poor Children Gratis," and the project went ahead so fast that building construction began before the land, at Fourth and Arch Streets, had been legally acquired, and the building began to be used before the roof had been put on it.[16]

Franklin published, May 14, 1743, "A Proposal for Promoting Useful Knowledge among the British Plantations in America," of which the immediate effect was the establishment of the American Philosophical Society and a more remote one was the starting of an Academy, of which Franklin became a trustee in 1749. This occupied the same building as the Charity School, but the proceeds of a lottery about 1750 provided funds for the purchase of more land. An attempt[36] to secure Samuel Johnson, who shortly after became the first president of Kings College (Columbia), as rector of the Academy was unsuccessful. A charter for "The Trustees of the Academy and Charitable School in the Province of Pennsylvania" was secured in 1753, and was changed in 1755 to "The Trustees of the College, Academy, and Charitable School of Pennsylvania." John Morgan, a graduate of the Academy in 1757, who had taken an M.D. at Edinburgh in 1763, was appointed professor of "Theory and Practice of Physick" in 1765. This was the first medical school in America and it gave 90 bachelor degrees in physics before 1790, after which it gave only the doctor's degree. The charter of the College was canceled by the legislature of Pennsylvania in 1779, and a new one creating a University of Pennsylvania was issued to a different set of trustees. This created a period of confusion, extending until 1789, when in a general reorganization Dr. Caspar Wistar was appointed professor of chemistry and Benjamin S. Barton professor of natural history and botany. Wistar was soon succeeded by James Hutchinson as professor of chemistry. The early connection of this medical school with chemistry and mineralogy has been discussed in chapter 2, and need not be again reviewed.

William H. Keating, who took his A.B. degree in 1816 from the University of Pennsylvania, went to Europe and continued his studies, chiefly of chemistry, in various schools there. He was at Freiberg in 1819; the first American student who appears in its records. After his return he published an 87-page pamphlet entitled "Considerations on the Art of Mining—and Advantages which Would Result from an Introduction of this Art in the United States." It is interesting that while he discusses the supply and cost of imported skilled labor at some length he does not suggest the possibility of training unskilled labor. The next year he was appointed professor of mineralogy and chemistry at the University of Pennsylvania and in 1823 was geologist for the Long expedition to the headwaters of the Mississippi. He published a 2-volume account of this expedition, and in 1824 was one of the prime movers in organizing the Franklin Institute, accepting election as its professor of chemistry. He resigned his professorship at the University of Pennsylvania in 1828, studied law, went into politics, and became one of the organizers of the Philadelphia and Reading railroad.

In 1850–51, James C. Booth was appointed professor of Chemistry as Applied to the Arts, and the next catalogue listed a department with that name, with Booth as "principal," offering courses in mineralogy, geology, theoretical, and applied chemistry. Separate fees were charged for these courses and apparently they were not credited toward a degree. In 1855–56 a Department of Mines, Arts, and Manufactures was created, with John F. Frazer, professor of natural philosophy, as its head; Fairman Rogers, professor of civil engineering; C. B. Trego, professor of geology, mineralogy, and paleontology; and a chair, not filled, of technical chemistry, metallurgy, and mining. The instruction was by "informal examinations and conversations" and extended from November until March. From five students in the first year the number gradually increased to 18 in 1859–60, but the work was never credited toward a degree.

Meanwhile an institution offering a degree for a curriculum in mining had been established in Philadelphia. Alfred L.

Kennedy, who was born there in 1818, and attended its schools, had become assistant to the professor of chemistry in the Pennsylvania Medical College when that institution was established in 1839. He retained this connection until 1843, lecturing on chemical physics, general and medical botany, medical jurisprudence and toxicology, which seems rather an undertaking before attaining the age of 25. In 1842 he organized the Philadelphia School of Chemistry and became its head; in 1848 he received his M.D. degree from the medical department of the University of Pennsylvania. One of his published biographies indicates that he studied at three or four European universities, but it is difficult to fit this in with the other dates. He was professor of medical chemistry in the Philadelphia College of Medicine from 1842 to 1852 and lecturer in agricultural chemistry for the Franklin Institute in 1852.

Early in 1853 he secured from the legislature a charter for the Polytechnic College of the State of Pennsylvania; this was the first institution in the United States to offer a curriculum leading to the B.S. degree in mining engineering. The act of the legislature approved April 5, 1853, reads, in part, as follows:

> Sect. 1. That Peter A. Browne, George H. Burgin, Garrick Mallery, Morton McMichael, John McIntyre, John Agnew, John Tucker, Samuel Jones and Matthew Newkirk, of the City of Philadelphia; John P. Veree, D. Francis Condie, Joseph S. Silver, Furman Sheppard and Alfred L. Kennedy, of the County of Philadelphia; Henry A. Muhlenberg, of Berks County; David Landreth and Daniel M. Keim, of Bucks County; Francis W. Hughes, of Schuylkill County; Thomas H. Burrowes, of Lancaster County; Luther Kidder and John N. Conyngham, of Luzern County; William Jessup, of Susquehanna County; George Smith, of Delaware County; Joseph Baily, of Perry County; James Hamilton, of Cumberland County; Joseph Henderson, of Washington County; and Daniel Agnew, of Beaver County; all in the State of Pennsylvania, and their successors, shall be and the same are hereby constituted a body politic and corporate, under the name, style and title, of the Trustees of the Polytechnic College of the State of Pennsylvania, and by the same name shall have perpetual succession, and be able to sue and be sued, plead and be impleaded, in all Courts of Record and elsewhere, and shall be competent and capable in law and in equity, to take and to hold to them and their successors, for the use of the said College, lands, tenements, hereditaments, moneys, goods and chattels, of whatever kind, nature or quality soever, by gift, grant, bargain, sale assurance, will, devise or bequest, from any person or persons capable of making the same:
>
> Sect. 5. That the object of said College, shall be the education of youth in the Arts, Sciences, Languages and Literature, particularly Mining, Engineering,

and the Natural Sciences, in their applications to the Arts and Manufactures; and the President and Professors, or a majority of them, shall constitute the Faculty of the College, which Faculty shall have the power of enforcing the rule and regulations, adopted by the Trustees for the government of the Students, by rewarding or censuring them, and finally by suspending such of them, as after due admonition shall continue disobedient and refractory, until a determination of the Trustees can be had.

The only announcements of the School I have been able to find are those of 1854–55, 1855–56, and 1862–63. A four-page statement regarding the School of Mines, dated 1859, has also been preserved. The 1854–55 announcement contains a five-page statement as to the need for the objectives of such a school, to cover the fields of Engineering, Mechanics, Chemistry, Mining, and Agriculture, and the second contains a similar but briefer statement. Reference is made to the "college edifice" at the corner of Market St. and West Penn Square, Philadelphia, which had an analytical laboratory "provided with furnaces, apparatus, tests, and reagents, for the performance of metallurgic processes," and to a mineralogical cabinet. The first announcement lists Alfred M. Kennedy, M.D., professor of metallurgy, and of industrial, analytical, and agricultural chemistry; William B. Thomas, professor of mining engineering, mineralogy, and geology; and S. H. Peabody, professor of mathematics and civil engineering. A professorship of mechanical philosophy and the principles of machinery was still vacant, and three other professors, of drawing, of French and Spanish, and of German, are listed as "not of the governing faculty." The 1855–56 announcement shows Hiram H. Boucher as appointed to the chair of mechanical philosophy and William S. Rowson as taking the place of Thomas as professor of mining and geology. The courses proposed are set forth in some detail, as indicated by the following statement for mining engineering:

Mining Engineering:—Geographical Distribution of Mines, Order of Exploration; Processes of Excavation; Employment of Tools and Powder; Boring; Quarrying; Subterranean Excavation; Shoring, Draining, Ventilation; Davy's Lamp; Elevating, Crushing, Screening, and Transportation.

The 1862–63 announcement gives the following synopsis of instruction in metallurgy:

Metallurgy.—Smelting of Iron; Ore, Fuel, Flux; Qualities of Pig Iron; Puddling, Refining, Forging Rolling; Employment of Waste Gases and Heat;

Blowers; Patterns, Moulding, Casting; Nature and Manufacture of Steel; Metallurgy of Zinc, Lead, Tin, Copper, Silver, Etc.

Visits to Smelting and other furnaces, in and near the city, will be made from time to time.

It also records that on June 26, 1862, the degree of Bachelor of Mine Engineering was conferred on Henry R. Clark, of Trenton, N. J., who submitted a thesis on zinc and its metallurgy, and on John Jungerich, of Darby, Pa., whose thesis was on copper and copper smelting. Twelve other degrees, mostly in civil engineering, were conferred at the same time, and one master's degree, in civil engineering, was given.

The names of all the graduates prior to 1890 are given in an alumni list published that year, 369 in all, and the school seems to have then gone quietly out of existence.[10] Why it did not meet with more success than it did is a question. Kennedy must have been too occupied* with administrative problems to teach effectively the subjects for which he was responsible. Frederick Overman died in Philadelphia the year before the School was started; it was unfortunate that he was not available to teach metallurgy, of which Kennedy could not have had much knowledge.

A two-year mining course was prescribed, as follows:

MINING ENGINEERING COURSE

FIRST YEAR	SECOND YEAR
Mathematics	Geology
General Chemistry	Mining Engineering
General Physics	Applied Mechanics
General Mechanics	Metallurgy
Mineralogy	Industrial Physics
Drawing	Drawing
	Mineral Analysis

This announcement also lists by name 34 students as having matriculated in 1854–55, and records that a "Certificate of Proficiency in Civil Engineering" was awarded to Thomas A. Budd, Jr., at the commencement exercises on June 29, 1855.

It will be noticed that great emphasis is laid on mining and metallurgy in these two early announcements, and the chief interest of the staff would seem to have been in them. But in the

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* From 1861 to 1865 he was in the medical corps of the Union Army, and eventually was commissioned a Colonel of Engineers.

1862–63 announcement, though the faculty had increased in number to eight, the professorships of both mining and metallurgy had disappeared, and Kennedy's title is given as professor of geology, mineralogy, and general and applied chemistry. As he was simultaneously the president of the School and undoubtedly much occupied with the problem of financing it, he can scarcely have been able to give much time to academic instruction. Henry Seybert was then living in Philadelphia and would have been an excellent man in the field of mineralogy, geology, and chemistry, but evidently was interested in other matters at the time.

About 50 or more of the graduates prior to 1890 were later connected with the mineral industry, but of them J. P. Wetherill and R. H. Sanders are about the only ones who had taken the mining course and later become prominent in mining. Most of the others, like Frank and Harry Firmstone, had taken one of the other engineering courses. Apparently the mining curriculum offered did not attract the best students, for the reasons indicated above.

There is no record that the State gave the College any financial support other than a single appropriation of $5000; and the income from students' fees, at $140 per year, must have been small. Probably the College was unable to offer a reasonable salary to men to teach mining and metallurgy, and Kennedy had to attempt to carry them himself. Though president of the faculty, Kennedy was not president of the Board of 26 Trustees, and this also may have added to his difficulties. Whatever the explanation, the School did not permanently succeed and the fact that it was the first institution in the United States to offer a curriculum leading to a degree in mining engineering has been generally forgotten, apparently.

An interesting event in 1858 was the passage of an act by the legislature of New York, incorporating the American School of Mines. It is entitled "An Act for the Incorporation of the American School of Mines for developing the mineral wealth of the United States," and was passed April 14, 1858. The pertinent parts of the act are as follows:

> The People of the State of New York, represented in Senate and Assembly, do enact as follows:

SECTION 1.—Isaac Ferris, Horace Webster, Peter Cooper, Charles M. Wheatley and Robert G. Rankin, of the city of New York, George J. Pumpelly, of Owego, and Thomas W. Olcott and James H. Armsby, of Albany, and all persons now composing the "American School of Mines," and all persons who shall hereafter become members thereof, are hereby created a body corporate by the name of the "American School of Mines," and shall have all the powers of a corporation, and shall be capable of taking, holding and conveying real and personal estate for the use and purpose of said corporation as a school of mines, but the annual net income thereof shall not exceed the sum of twenty thousand dollars in any one year.

SECTION 2.—The object of the "American School of Mines" shall be the economic and scientific development of the mineral wealth of the United States, the determination of its economic values, instruction in the art of practical mining, and the analysis and composition of mineral products.

SECTION 3.—The organization and management of the corporation shall be as follows:

1. A council of twenty-four members, . . .
2. A faculty to consist of professors of practical mining, dynamic and economic geology, mineralogy, general and analytic chemistry, metallurgy, applied science, physics and such other branches of science and art as may become requisite.
3. A resident curator of the museum, who shall have the general supervision of the same, under the direction of the president and council.
4. An assaying office and laboratory, and mining library.
5. A museum of practical geology and mineralogy, for the collection and preservation of mineral products, and the application of their usefulness in the arts of life; models, plans and drawings of mines; description of deposits and basins; specimens of all the tools and implements used in mining, and generally every matter and thing relating to, or capable of accomplishing the objects of the corporation.
6. Life directors and life members.
7. Honorary directors.
8. Members.

SECTION 7.—The corporation may grant to students, attending its course of instruction, for skill in any department of mineral economics and the art of mining, such diplomas or testimonials as may indicate their proficiency, and in such form as may be requisite; but no diplomas shall be conferred but in conformity with the laws of the state in force at the time of conferring the same.

SECTION 9.—This act shall take effect immediately.

The curious thing about the School thus authorized is that immediately thereafter it disappeared from view, and the brief allusion to it (about 75 words) that appears in Moses' biography of Egleston[38] is almost the only subsequent reference to it that I have been able to find. A brief consideration of the names of the incorporators increases the wonder why a group of such prominent men started something which they were unable, or unwilling, to finish.

Isaac Ferris, the first named of the incorporators, had been Chancellor of the University of the City of New York since 1852 and was extremely busy in trying to build up that institution (now New York University) which, at the time he went to it, was described as "moving rapidly toward chaos." Horace Webster had been the principal of the Free Academy in New York since 1848. This school was established by the Board of Education in 1847, and in 1866 it became the College of the City of New York. Peter Cooper had been moving since 1852 toward the establishment of Cooper Union, had secured the act of the legislature "to enable Peter Cooper to found a Scientific Institution in the City of New York" on Feb. 17, 1857, and was engaged in putting up the building in 1858. Charles M. Wheatley was a business man who had been manager of the Bristol mine in Connecticut and more recently manager and part owner of the Wheatley lead-silver mine at Phoenixville, Pa. Later he established the Schuylkill copper works there. Yale bestowed an honorary A.M. on him in 1858. George J. Pumpelly was the uncle of Raphael Pumpelly, who in 1866 became the first professor of mining at Harvard, but in 1858 was studying at Freiberg. Thomas W. Olcott had been president of the Mechanics and Farmers Bank of Albany since 1836, and was president of the Board of Trustees of Albany University. James H. Armsby, who had been professor of anatomy and physiology at the Vermont Academy of Medicine 1834–40, went to Albany in March in 1851 as assistant to Dr. Alden. Armsby and March had been active in trying to establish a medical college at Albany for many years.

It would take us too far afield to review the history of the attempts to establish a university at Albany. A pamphlet published in 1852 outlines its proposed Scientific Department, and one paragraph says: "Civil and Mechanical Engineering—Including Architecture, the Arts of Design; Mathematics, Geology, and Mineralogy applicable to Engineering and Geographical Surveys; also Metallurgy, and the Science and Art of Mining." In 1873 the Law School and the Medical College (which were all that had then been brought to realization) were merged with Union College. But in 1858 Armsby and Olcott were doubtless keenly interested in the possibility of establishing a School of Mines at Albany.

Robert G. Rankin, a lawyer of Newburgh, N. Y., was general agent and consulting engineer of the Boston, Hartford, and Erie Railroad, and had been a regent of the University of the State of New York since 1847. In the absence of definite information, it is natural to infer that Rankin was persuaded to lend his name to the movement, as concrete evidence that it had the approval of the State University, with its general supervisory powers over education in New York State. Cooper could not have had any personal interest in it, as he was absorbed in a totally different project, but he was an ardent supporter of education in general and a kindly man who was always ready to support what he believed to be good works. It was good practical politics to include him among the incorporators, as he was well known to the members of the legislature and his name among the incorporators would greatly facilitate securing votes for the bill. Ferris and Webster may have been included for a similar reason, for they hardly would have been much interested unless there was a possibility of placing the proposed School at one of their institutions. Webster would scarcely have wished this, as he was developing what was then little more than a high school into a college that was not for many years to attempt to venture into the field of professional education. Olcott and Armsby were trying to found a university at Albany, but neither was directly interested in mineral industry education; they would doubtless have welcomed a School of Mines at Albany but are not likely to have initiated the idea. This leaves Pumpelly and Wheatley as the two who might conceivably have been its originators.

No records seem to be available to reveal why George Pumpelly should have been interested in mineral industry education and the material on the life of Wheatley is also scanty. But he must have been in New York in 1858, as he was then treasurer of the New York Lyceum of Natural History and had been active in its affairs since 1840. He was a collector of minerals, books on geology and mineralogy, and shells; eventually his collections were bought by Edward C. Delavan and given to Union College. It seems plausible that he may have been the active promoter of the project, as the bill was introduced into the legislature by

George W. Bleecker of Brooklyn (7th district of King's County). It is also quite possible that the person, or persons, who initiated the project was not included in the group of incorporators, who were selected for the reasons indicated.

The mystery as to why and how the project to establish the American School of Mines was started is exceeded only by the mystery as to why nothing more was done after the charter was secured. A guess that it may have had something to do with the panic of 1857 seems inadmissible, because in April 1858 the panic was over and business was reviving; by autumn the mills of the Trenton Iron Works were pushed to capacity and were refusing orders for railroad rails. What seems more plausible is that Olcott and Armsby perhaps insisted on the School being established at Albany, and though the others may have formed a majority favoring New York, Olcott's importance in the banking world may have defeated the possibility of financing a school in New York City. Whatever the reason, nothing eventuated from the project, and the effective impulse toward starting a School of Mines in the United States eventually came from men who had nothing to do with this attempt.

It is not at all unlikely that the circumstances that so definite an attempt had been made to start a School of Mines in New York State had no little effect in facilitating the second and successful attempt, but there is nothing in the record to show it.

When the cornerstone of what is now the University of the South, Sewanee, Tenn., was laid in 1860, the original plan called for a School of Mines as a part of the projected university. Little was accomplished before the Civil War broke and it was not until 1868 that the building of the present college there was resumed. The war had swept away the original endowments, the area was impoverished for years, and nothing was ever done in regard to a School of Mines.

Chapter 5

THE COLUMBIA SCHOOL OF MINES

TWO American students entered the École des Mines in 1856, Joseph Lesley of Philadelphia and Thomas Egleston of New York. Lesley remained there only one year, but Egleston completed the whole curriculum and received, in 1860, the certificate given to foreign students in lieu of the official appointment and degree awarded French students. Returning home he received, in 1861, an appointment by Secretary Henry of the Smithsonian Institution to sort, label, and arrange the collections of mineralogical and geological specimens which had been brought to Washington by the various government exploring expeditions in the West.

Thomas Egleston, born in New York City on Dec. 9, 1832, was the son of Thomas Jefferson Egleston, who came to New York from Massachusetts some time before 1829. The first American ancestor of the family had settled near Dorchester in 1630. T. J. Egleston and Joseph Battell established an iron-merchandizing business* at 166 South St., New York, which prospered exceedingly; so much so that when Thomas J. Egleston died, July 12, 1861, his estate had a book value of over $500,000. Since an older brother was expected eventually to take over this business, Thomas, who had a liking for science, went to Yale, where he completed the regular four-year course in 1854, and then remained another year for advanced work in chemistry under Silliman.

One biographer says he went to Europe, early in 1856, on account of his health. It was the custom at that time for wealthy young men to make a tour of Europe after completing their academic education. Whatever the precise reason, he began scientific work at the Jardin des Plantes in Paris but soon transferred to the École des Mines, because that institution had so much better facilities for the study of mineralogy, in which he had now become interested. Why he took the full mining course is not clear, for apparently he never expected to have to make a living and, as he expressed it in a letter many years later, mineralogy was "his passion."

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* It is still operating as Egleston Bros. Inc., though no direct descendants of its founder are now living.

His early correspondence has not been preserved, so it is not known how he made his connection with the Smithsonian Institution, but such records as remain indicate that he did much of the work either at the family home, 10 Fifth Avenue, New York, or at their summer home at Lenox, Mass. He was working in Washington, however, from the beginning of February 1862 until early in August of that year. His father had died the previous summer, and his scientific work apparently had to take second place to family responsibilities. When he conceived the idea of trying to establish a School of Mines in the United States is not known, and the statement, made by others, that he endeavored, without success, to secure the aid of the Smithsonian in establishing a National School of Mines in Washington is not supported by documentary evidence. One of his colleagues, 50 years later, said that Egleston also tried to interest Peter Cooper in establishing a School of Mines in connection with the institution he was creating and that Cooper replied "Why, Egleston, you propose to give a good deal of education to a small number of men. The scheme of the Cooper Union is to give a moderate amount of education to a large number of men. The two schemes are diametrically opposed to each other. You can't fit the School of Mines into Cooper Union." Here again there is no documentary evidence of negotiation, but such a casual conversation may well have occurred.

Egleston was acquainted with George T. Strong, a prominent New York lawyer who was one of the Trustees of Columbia College, and apparently arranged and labeled a mineralogical collection for him. On Jan. 10, 1863, Strong gave Egleston a letter of introduction to Charles King, then president of Columbia College, so that Egleston could arrange for the transfer to Columbia of this collection. Egleston met Charles Joy, professor of chemistry, and transferred the collection to him. The next documentary evidence is a printed pamphlet, dated March 1863,[18] by Egleston, which apparently was issued at his own expense, entitled "Plan for a School of Mines and Metallurgy in New York City." It estimated that the cost of establishing such a school would be $17,000 to $18,000. At the next meeting of the Columbia Board of Trustees, April 6, 1863, this plan, and the report that "the Legislature had in contemplation a design of making a large grant of lands for the purpose of aiding scientific instruction," was discussed and a committee of three trustees was appointed to report on it.

Columbia College was then almost 110 years old, having been founded by royal charter as Kings College in 1754. It graduated six students in 1776 and was rechartered in 1784 by the legislature of the State of New York, taking the name of Columbia College. The buildings on the original site, west of the present Woolworth Building, were enlarged, and the institution grew slowly there until 1857, when it was removed to the block bounded by 49th and 50th Sts. and Madison and Park Avenues. There, in 1862, it had a staff consisting of a president and ten professors, an annual income of about $68,000, and a student body of 186. Its curriculum was the traditional one, centering on the language, literature and culture of Greece and Rome, history, rhetoric, logic, mathematics, and some instruction in physics and chemistry. Before 1820 one man taught all the natural sciences, but in that year Robert Adrian was made professor of mathematics and astronomy, while James Renwick, of the Class of 1807, was made professor of Natural and Experimental Philosophy and Chemistry. For 30 years he covered this broad field of instruction in a surprisingly thorough manner. On his resignation in 1853, there was delay in filling the vacancy, but in 1854 Richard S. McCulloh, then professor of physics and chemistry in what is now Rutgers College, was called to the chair. In 1857 it was again divided and Charles A. Joy was brought from Union College to be professor of chemistry.

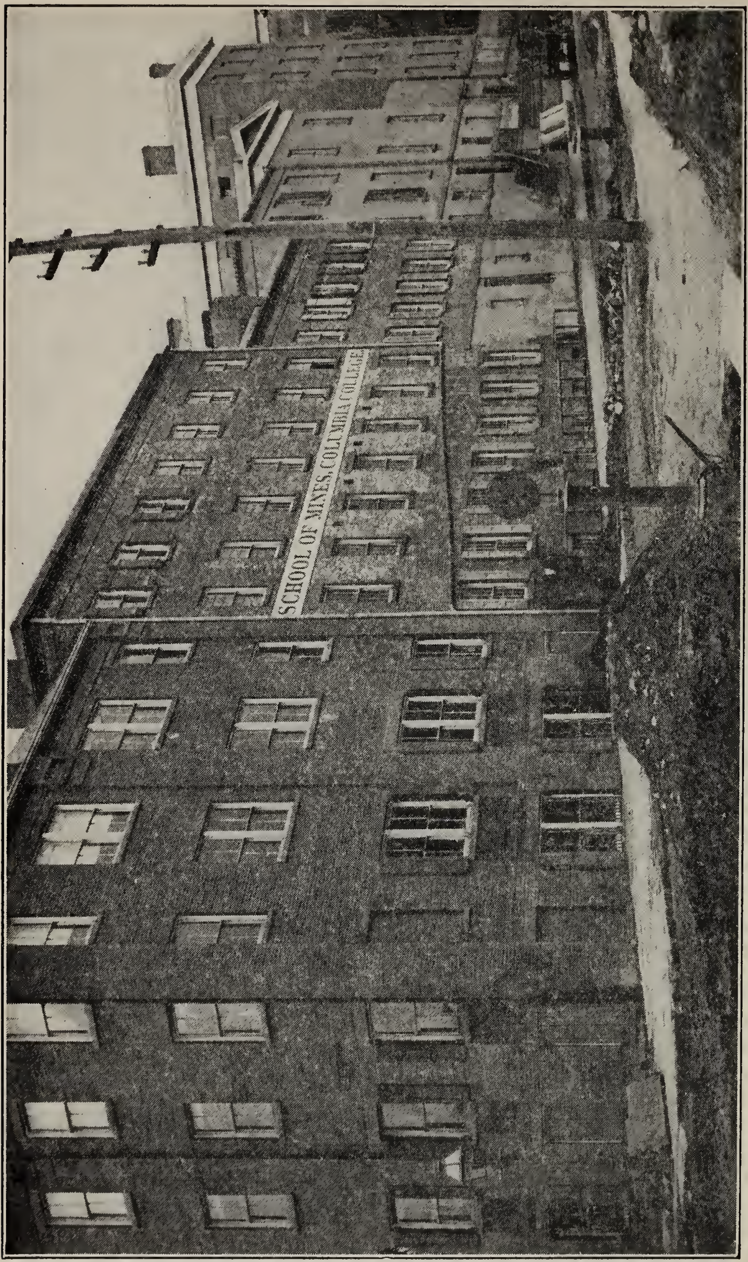
Though Columbia had at the time an arrangement with the otherwise independent College of Physicians and Surgeons to grant degrees in medicine, and gave degrees in law for a school conducted by Theodore W. Dwight in Lafayette Place, it was concerned as to its further development and had voted to establish a graduate School of Science and to grant master's degrees.

Professor Joy had been endeavoring to establish a School of Chemistry, and it was actually advertised in the New York papers as opening on Nov. 1, 1863, but his efforts were not well coordinated with the plans of the Trustees, with the result that the much stronger and better directed impulse toward establishing a School of Mines swept it aside and submerged it.

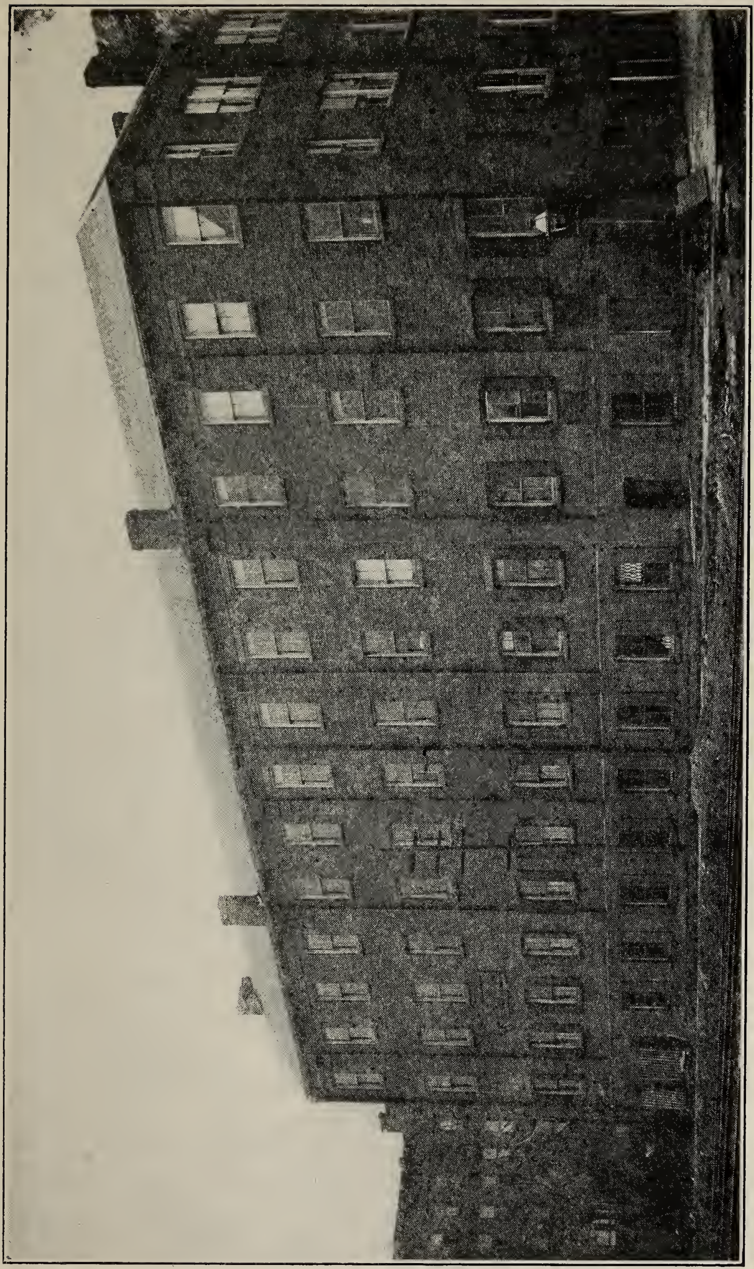
The special committee of the Trustees, on April 29, 1863, reported favorably on establishing a School of Mines, and the problem of the Columbia Trustees was how to do it without getting beyond their financial depth. Eventually it was worked out in a clever manner. The plan was to have most of the instruction given on a volunteer basis by the faculty of Columbia College. Three new professors were appointed. Egleston himself offered to cover the subjects of mineralogy and metallurgy. Francis F. Vinton, who had been his classmate at the École des Mines in 1857–60, had fought in the Civil War (he was a graduate of West Point) and was retired as a brigadier general on account of wounds in March 1863, was made professor of mining and Charles F. Chandler was brought from Union College to be professor of analytical chemistry. None of these were assured any salary. Chandler was the only one of the three to whom apparently it mattered much, and he was given private assurance that he would not suffer by giving up the $1500 a year he had been getting at Union. It was understood that if the proposed School was a success due provision would be made for the salary of these three men. Egleston's appointment was authorized in December 1863, and the others were made early in 1864.

Meanwhile a score of prominent citizens had been appointed as "associate members" of the special committee of the Trustees on the School of Mines, now enlarged to six members. Subscription blanks were circulated, but the amount thus raised was small, and some of it was earmarked for the purchase of mineralogical collections. Alterations to provide space for classes, especially in analytical chemistry, were made in one of the existing buildings on the 49th St. site, at a cost of $3500, and the School was officially opened on Nov. 15, 1864.

The extent to which the venture was successful seems to have been somewhat of a surprise to everyone concerned. Twice as many (24) students appeared on the first day as had been pro-



Columbia School of Mines, the first building of its kind in the United States.
This was a remodeled factory on 50th Street west of Park Avenue, New York. Occupied November 1865.



Columbia's second School of Mines building.
Constructed in 1866, but torn down and rebuilt as shown above in 1874.

vided for. Tuition was $160 per year, though a couple of men received free tuition for acting as laboratory and classroom assistants. The average age of the students was 23 years; two of them already had A.B. degrees, one a C.E., and one an A.M. Altogether, 44 were recorded as having been in attendance during the first year. The Trustees were not dismayed by the increased expenditures entailed and early in 1865 voted to approve a budget of $28,000 for the ensuing year, of which fees would provide only $16,000. A separate building on 50th St. was set aside for the School, which moved into it during the summer of 1865. Salaries of $3000 each were provided for Egleston, Vinton, and Chandler, and those college professors who had been giving instruction in the School on a volunteer basis were designated members of its faculty.

In March 1865 the School was firmly established by the adoption by the Trustees of statutes creating a faculty of the School, regulations for the operation of the School, and provision for the granting of degrees. Early in October 1865 the Faculty met and organized by electing Chandler as Dean. At its meeting in December the Faculty requested the Trustees to appoint a professor of geology, which Chandler had taught to nine students in 1864–65. The total number of students enrolled in 1865–66 was 97, a close approximation to the 100 estimated. Early in 1866 the trustees appointed John S. Newberry professor of geology, also at $3000 per year. A new three-story brick building was erected during the summer of 1866, on Park Avenue at the 50th St. corner, and the tuition fee was raised to $200 per year.

While these definite things were being done, there was not perfect certainty as to the precise aims and purposes of the School. The Trustees had intended, 10 years earlier, to establish a graduate School of Science. Frederick A. P. Barnard, who had succeeded King as president of Columbia on May 18, 1864, lent hearty support to the School of Mines project. In his official report for 1865–66 he spoke in high praise of the success it had already attained, and added, "with the School of Mines there may easily be associated, and that perhaps at no distant date, a School of Civil Engineering." Very likely it had been the idea of Egleston that the School of Mines should train only mining engineers and metallurgists. It may be remembered that Cornell, which started about the same time, later organized its engineering instruction into separate schools of civil engineering and mechanical engineering. A similar course might have been followed at Columbia.

Very likely Professor Chandler* was the principal factor in determining the direction which development took. Not yet 29 years old when he was elected dean of a school whose possibilities were indicated by its auspicious beginning (during its second year it had half as many students as the college had acquired in over a century of life), he must have been familiar with Joy's attempt to establish a separate School of Chemistry, and may have concluded (though there is no documentary record to support the hypothesis) that it would be more advisable to build up chemical instruction within the School of Mines framework. Possibly there was not very much planning about it; like the man in the old story, it may merely have seemed like a good idea at the time.

Whatever the precise reasons, the Faculty made a report to the Trustees on March 22, 1866 (in response to a request for a recommendation as to what degrees should be granted), suggesting that in addition to the Engineer of Mines degree, to be given for completion of the three-year mining curriculum, the Bachelor of Philosophy degree should be given to students "who shall have passed such approved examinations upon the studies of either of the following groups, viz—." The two groups had a common core of physics, mineralogy, and geology, but one stressed chemical and the other engineering subjects. The evident objective of this was to develop the School of Mines into a generalized school of applied science. A third recommendation was that the degree of Doctor of Philosophy should also be conferred on men the Faculty deemed worthy of it. Frequent references to the "undergraduate students" of the College suggest that from its beginning the School of Mines was thought of as a graduate school.

These matters were under constant discussion during the next two years, and in the spring of 1868 crystallized into five definite

* Chandler should be the patron saint of all assayers, since in 1866 he invented, but did not patent, assay-ton weights. Containing the same number of milli-

curricula, recommended by the Faculty and approved by the Trustees, leading to the degree of Mining Engineer, Civil Engineer, and the Bachelor of Philosophy degree for curricula in metallurgy, chemistry, and geology. These curricula had been lengthened to four years, and though the first year was called "preparatory" it was not really so, for its mathematics, physics, chemistry, drawing, French, and German were as advanced as the instruction given in those subjects in the first year of a typical engineering school today. Probably it was feared that a straight four-year curriculum would seem too long to prospective students. The soundness of such a view is suggested by the fact that attendance declined during the next few years, and it was not until 1872–73 that it exceeded that of 1866–67.

In this way the Columbia School of Mines, while retaining its original name, had been reorganized during its first five years into a general school of technology. Professor Vinton's title was changed from professor of mining to professor of civil and mining engineering; Chandler's had been changed from professor of analytical chemistry to professor of analytical and applied chemistry several years earlier. The added curricula did not attract many students at first, only about one entering civil engineering and geology each year for the first two years. Very few men ever took the Ph.B. in metallurgy and while the attendance on the chemical curriculum grew it was only slowly. Possibly the Ph.B. degree was not desired because of its indefinite character; at any rate practically all the students continued to be candidates for the Engineer of Mines degree.

Further consideration of the development of this first successful School of Mines in the United States had best be postponed until happenings at the other schools that began instruction in the mineral industry at about the same time have been recorded. The main reason for according it the dignity of a separate chapter is to emphasize its form of organization, which is believed to have been not only important to itself but also to have influenced subsequent developments elsewhere in subtle ways. It will be remembered from chapter 1 that it was early proposed to turn

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grams as there are Troy ounces in an avoirdupois ton, they have saved an uncalculable amount of mental effort in reporting results.

the School of Mines at Freiberg into a university, but this met with opposition. The unwillingness of scholars in the classical tradition to admit that the study of technology, or even of its natural sciences, was really scholarly and merited the prestige accorded to philosophy, rhetoric, and logic, was equally perceptible in the United States, so that many technical schools were organized as separate institutions. At Columbia the professors in the College were persuaded to volunteer to teach in the School of Mines, were given seats on its faculty, and the School was spoken of as a "graduate" school, thus forestalling any tendency to look down on it. It was more difficult to enter than the College, the academic work was harder, and the quality of work done by the students after graduation made it evident that an engineering degree was as much the mark of an educated man as an arts degree. This must have had a good deal of effect in winning recognition for engineering as a learned profession.

Another influence will be indicated in later pages by names of educators who are known to have studied at Columbia. A few may have been overlooked, and in many cases other degrees have also been indicated. Where the degree is omitted it is because it was not known and impracticable to ascertain without an amount of labor that would have been excessive in proportion to the advantage of giving it. Though thus imperfect, some indication will thereby be given of the influence of this school on general mineral industry education during its early development in the United States.

Chapter 6

OTHER SCHOOLS

IT is difficult to judge how much influence the success attained during its first year, 1864–65, by the School of Mines at Columbia had on developments in education for the mineral industry elsewhere in the immediately subsequent years. The facts are as follows:

1. The Massachusetts Institute of Technology began giving instruction in February 1865, with a mining course included in its curriculum.

2. Early in 1865 the faculty of the Department of Science, Literature and the Arts of the University of Michigan requested permission from the Regents to establish "a course of study to be called the School of Mines . . . Also that the degree of Mining Engineering be conferred on students who should complete the course of study prescribed in the same." A resolution authorizing this was adopted by the Regents on March 28, 1865.

3. Samuel Hooper endowed a Sturgis-Hooper professorship of geology at Harvard in 1865 with the intention of making it a nucleus of a new School of Practical Mining and Geology.

4. Yale appointed Alfred P. Rockwell professor of mining in 1865.

5. Lafayette College appointed Henry S. Osborn professor of mining and metallurgy in 1865.

6. Washington College (as Washington and Lee was then known), rising out of the ashes of Civil War destruction, made a fresh start in 1865, with General Lee as its president, and offered a mining course in the first catalogue thereafter published.

7. Lehigh University, founded in 1866, had a mining curriculum from its beginning.

8. Rensselaer Polytechnic began offering a curriculum in mining and metallurgical engineering in 1867.

It would be natural to suppose that these events were a reaction to the success of the school at Columbia, and possibly they were, to some degree, but the original "Objects and Plan for an Institute of Technology," published by W. B. Rogers and his nineteen associate committee members in Boston in 1860, included among its five schools one of geology, which was to provide "systematic teachings in physical geology and mining, with so much of the general science as is important to illustrate the more practical branches of the subject." Rogers' activities in Boston are the most likely reason for renewed interest in mining instruction at Harvard. Yale had appointed a professor of metallurgy as early as 1855, as has already been related.

The University of Michigan had been setting up scientific courses since 1850 and the steady increase of copper production from the Keweenaw peninsula from 1845 to 1862 (and possibly its decline between 1862 and 1868) furnished a reason for interest in formal instruction in the technology of mining.

Lafayette College was founded at Easton, Pa., in 1826 in a burst of local patriotic and educational fervor, following the triumphal return of Marquis de Lafayette to America in 1824–25. Gaining the support of the Presbyterian Church in 1849, it had been wishing to add engineering to its curriculum, and, because of its nearness to the anthracite districts, naturally had an interest in mining. The latter was also true of Lehigh, founded in 1866, and Asa Packer, who furnished the initial impulse for it and gave a half-million dollars and a tract of land to start it, had acquired his wealth through mining and transporting anthracite. Thus all of these institutions had their own reasons, some of them of long standing, for wishing to start systematic instruction for the mineral industry. But undoubtedly news of its successful initiation at Columbia was helpful in crystallizing their intentions.

It would be helpful in visualizing what actually happened at the institutions just mentioned, and the others which began to give mineral industry instruction in the period 1865–1890, to compile a table showing the number of mining degrees granted by each in these years. A. M. Wellington did prepare such a table and published it in his series of articles on engineering education, which are discussed in more detail in chapter 9; it appears on page 140 of the *Engineering News* for Aug. 11, 1892. But prolonged study of Wellington's table reveals so many errors in it, and the difficulties involved in compiling an accurate table are so serious, perhaps insuperable, that it seemed wisest to abandon the idea. In some places the instruction was not credited toward a degree and at others, where it was credited and a B.S. or Ph.B. degree awarded, there are no precise figures as to how many should be credited to mining. Finally, the institutions differ in their records as to the year of attainment of degrees. For example, the official records of Columbia show 13 E.M. degrees granted in 1867, but detailed study of them shows that John Magnus Adams (who had taken the A.B. before entering) was the only one* of the thirteen who had completed all his work by June of that year. It was then the custom to permit students who had paid the fees for the number of years involved in the curriculum to continue their work, without payment of fees, until they completed it. Two men credited to the class of 1867 did not receive their E.M. until 1872. For all these reasons one hesitates to prepare a tabulation, which might present an appearance of accuracy it would not really possess.

It may be helpful, however, to present some of the features that would appear in such a table. The Polytechnic College of the State of Pennsylvania was the first American institution to grant mining degrees; it was founded in 1853 and granted two Bachelor of Mine Engineering degrees on June 26, 1862, but the records are too incomplete to be sure that these were the first awarded. It never gave many mining degrees, and went out of existence about 1890. Columbia and the University of Michigan granted 13 and 2 E.M. degrees, respectively, in 1867. Columbia thereafter gave such degrees every year, but Michigan awarded none in 1873 to 1877, inclusive, nor in 1881 to 1885, inclusive. There were only two years after 1869 in which more than three such degrees were awarded at Michigan. Massachusetts Institute of Technology gave six S.B. degrees in mining in 1868, but in only two years before 1884 was this number again reached. Rensselaer Polytechnic Institute gave 23 mining degrees in the four years 1868 to 1871, but none thereafter. Yale gave two mining degrees in 1868, three in 1869, and one in 1870, but none thereafter for many years. Washington and Lee gave four such degrees in 1869, one in 1874, and three in 1875, but none thereafter. Lafayette College gave one mining degree in 1870 and

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* Thus he was the first man to take the E.M. degree in the United States.

Lehigh University one E.M. degree in 1871. Lehigh did not give another until 1875; meanwhile the University of California, Missouri School of Mines, and Washington University each gave one in 1874. The University of Illinois gave one in 1878, and Wisconsin one in 1879.

The University of Ohio gave two mining degrees in 1880 and Colorado School of Mines gave its first E.M. degree in 1882. Michigan College of Mines gave seven B.S. degrees in mining in 1888. When the Iowa State College gave its first mining degree is not known. South Dakota School of Mines gave its first B.S. degree in 1888, possibly not in mining, as the man later entered the ministry. The University of Alabama gave four B.S. degrees in mining in 1888. No other institution gave mining degrees prior to 1890, so far as can be learned. During most of this period the Columbia School of Mines was awarding annually about as many degrees as all the other institutions collectively. In 1893 S. B. Christy[12] gave a table showing 871 mining graduates in the United States to 1892, of whom 402 are credited to Columbia. Since Christy apparently took his dates from Wellington's tables, the figures undoubtedly are not accurate, but they do show a general relation. More than a score of American institutions had begun to offer mineral industry instruction previous to 1890, but two had already permanently dropped mining engineering; several more, as related in this and in the succeeding chapter, were to drop it, and it is open to question whether the University of Pennsylvania, Harvard, and Yale had really begun it. What happened at the University of Pennsylvania has already been related (see p. 33), and the events at Harvard and Yale prior to 1865 have been reviewed in chapter 3. It will be of interest to set forth their later developments in some detail.

HARVARD

J. D. Whitney was selected to head the department of geology at Harvard, which Samuel Hooper had endowed. He was a Yale man, who had done graduate work at Harvard, had made Cambridge his headquarters while writing his "Metallic Wealth of the U. S." (published 1854), and had been appointed State Geologist of California in 1860 at Agassiz' suggestion. The story of what actually happened is told in Raphael Pumpelly's reminiscences[48] as follows:

> There was being created a new department of Geology at Harvard under the Sturgis-Hooper endowment, and it was to be organized by Prof. Whitney, who was to hold the chair of Geology. Whitney asked me to take the professorship of mining. Instruction would not begin till after several years, and he wished me then to lecture on geology until he should be ready to do it himself. Until the fund should have grown enough to give me a salary of $3000 I was to have $1500 yearly. The proposition as I accepted it would leave me free for several years.

Whitney did not go to Harvard until 1868, was then assigned to the Museum of Comparative Zoology as a research professor, with no teaching requirement, and thereafter took almost no interest in undergraduate matters. Pumpelly began his work there in the autumn of 1869 and says (p. 592 of ref. 48) "during the winter of 1869–70 I lectured at Harvard to three students, William Morris Davis, Henry Gannett, and Archibald Marvin." He continued these lectures, which were on economic geology, not mining, until the spring of 1871, when he resigned, not liking the climate of Cambridge and regarding the salary as too small.* William H. Pettee (who had taken his A.B. at Harvard in 1861) was appointed instructor in mining in 1869 and the same year Thomas M. Drown (an M.D. of the University of Pennsylvania in 1862, who later became president of Lehigh) was appointed instructor in metallurgy. Their appointments also were terminated in 1871, there were no students in mining in 1874, and the School of Practical Mining and Geology disappeared from the Harvard catalogue after that year. No Mining Engineer degrees were given at Harvard between 1875 and 1906,[37] though a four-year course leading to a B.S. degree in mining was again offered in 1894.

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* Van Wyck Brooks, in his "New England Indian Summer, 1865–1915"[7] pays high tribute to Pumpelly, whom he describes as a "Huguenot-Yankee Marco Polo" who "exerted a personal influence as strong as" Fiske, Holmes, Wright, Pierce and Howells, adding that he "remained only two years in Cambridge; but he fired the imagination of many a student." Two and a half pages of his book is devoted to Pumpelly and his influence on Harvard. This is worth recording, in contrast to Pumpelly's own modest estimate of the results of his stay there.

Various reasons suggest themselves for this failure to develop mining instruction at a strong institution like Harvard when a small and weak one, as Columbia was then, was meeting with such success in its attempt. One is the uncongenial atmosphere for applied science instruction at Harvard, another is faulty organization, which was rather like that of a school of philosophy at Athens 2000 years earlier. There seem to have been no entrance requirements other than "a good common English education" and the announcement of the Lawrence Scientific School for 1848 said "The number and choice of studies to be pursued are optional on the part of the students . . . Attendance on the lectures and recitations is voluntary." In other words, there was no mining curriculum, though a mining engineer degree was offered. But probably the main reason was that the students seeking mining education elected to go to Massachusetts Institute of Technology where, after 1870, there was a definite curriculum and the instruction dealt with practical techniques rather than pure science. Even at that school there were not many before 1890.

YALE

At Yale, Alfred D. Rockwell was appointed professor of mining in 1865. He graduated from the college in 1855, from the Scientific School in 1858, and went to Freiberg that autumn. On his return he went into the army and eventually became Colonel of the 6th Connecticut Infantry. He left Yale in the summer of 1867 to become professor of mining at Massachusetts Institute of Technology. Chittenden says,[11] "There were no funds available to retain Professor Rockwell," and his place was not filled. The Programme of Studies for 1868–69 says that mining and metallurgy were thereafter to be "a post-graduate course analogous to the higher course in engineering." But "there was no one on the ground really competent to deal with strictly mining subjects," and until 1901 all the Yale catalogue said was that "Young men desiring to become mining engineers can pursue the regular course in civil or mechanical engineering, and at its close can spend a fourth year in the study of metallurgical chemistry, mineralogy, etc." None seem to have elected to do so, as no degrees in mining were given after 1870.* Whether mining students would have been attracted to Yale if Rockwell had stayed there is anybody's guess. He had only a few at M.I.T. in the six years he was there.

MICHIGAN

At the University of Michigan no students were graduated in mining between 1872 and 1878, nor between 1880 and 1886. After 1869 there were only two years in which the number of mining graduates exceeded three, and eventually the mining curriculum was definitely dropped. Instruction in metallurgy continued to be offered under the auspices of the chemistry department, as a subhead of chemical engineering, and its later growth is recorded in chapter 13. Perhaps the clue to the otherwise puzzling failure of mining instruction to develop at the University of Michigan (then a much stronger institution than Columbia) is found in a sentence in the President's report for 1865, where he says, "The University of Michigan has not chosen to engraft upon itself scientific schools, with an imperfect and abnormal connection, but to develop together, harmoniously, and under one government, and largely under the same professors, various departments of investigation and culture. The experiment thus far is entirely successful." He goes on to say that the setting up of a Department of Mining Engineering through "increased provisions made to assist the professor of chemistry and by giving some additional labor to the professors of geology and civil engineering, can easily be accomplished." A three-year curriculum on this basis was arranged and two men were given the degree of Mining Engineer in 1867, six in 1868, seven in 1869, three in 1870, and one each year in 1871 and 1872. No more Mining Engineer degrees were then granted until 1876. After 1870 the curriculum provided for a four-year course.

No teacher of mining or metallurgy was appointed before 1875, when S. T. Douglas was appointed assistant in the School of Mines at $750 per year. A specific appropriation of the legislature (in 1865) for a School of Mines enabled them to bring to the staff W. H. Pettee, who had been instructor in mining at

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* There were two of Ph.B. in mining in 1868, three in 1869, and one in 1870. Two Ph.B. degrees in metallurgy were given in 1874.

Harvard 1869 to 1871.* The legislature did not renew its appropriation in 1877 and Pettee resigned as professor of mining, but was appointed professor of geology at a reduced salary, while Langley volunteered to give metallurgical instruction without pay. Four men were graduated in 1878, and three each year in 1879 and 1880. A committee of the Board of Regents recommended, Oct. 21, 1879, "that the course in mining engineering ought to be discontinued in view of the fact that the provisions for technical instructions on this subject were manifestly inadequate to give the full amount of instruction demanded by the standard of the best Mining Engineering Schools of this country." The Calendar for 1879–80 says, "The work and the organization of the School of Mines are dropped."

In spite of this definite announcement, the mining curriculum continues to appear in the Calendar for subsequent years. Two degrees of Bachelor of Science in Mining Engineering were given as late as 1892, and W. H. Pettee held the title of professor of mineralogy, economic geology and mining engineering until 1902–3. Thereafter metallurgy alone was taught, without any degree being given for it. The Engineer of Mines degree was first given for a three-year course, later for a four-year course, but after 1881 it was given only for additional work beyond the four years, for which a B.S. was given.

C. W. Good, assistant to the Director of the Engineering School of the University of Michigan, who has kindly made these data available to me, considers that the failure of the legislature to make a specific appropriation for mining instruction at the University of Michigan after 1877 was the reason it did not succeed there. Yet the legislature was sufficiently interested in mining instruction to establish a separate mining school at Houghton in 1886, and conceivably could have been interested in supporting it at Ann Arbor if there had been sufficient demand for it. The School at Columbia was started without definite financial support, and won it as it progressed. It seems to me that the real reason was that the first mining and metallurgical instruction at Michigan was given by men who were professors of other subjects; it was 10 years after the School was first started that Pettee was brought there to teach mining engineering, and he was a geologist rather than an engineer. In a statement he made to the Regents in October 1878 he said that when he first came to Michigan "there were no students far enough advanced to take up the special topics of mining and metallurgy," and he taught mineralogy and geology to students in the literary department and crystallography to the seniors in pharmacy. The basic difficulty apparently was that there were only a few students who wished to study mining engineering, which may have been because of the geographic situation at Ann Arbor or because the organization and personnel made it "only, as now organized, draw a small number of the body of students aside from the usual college routine," as Rogers in 1847 had prophesied would be the case at Harvard. At any rate, though the University of Michigan continued to grow into a great university, mining instruction there languished and died.

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* John W. Langley seems to have been professor of metallurgy and chemical technology.

Massachusetts Institute of Technology

The early development of mining instruction at Massachusetts Institute of Technology is recorded in R. H. Richards' autobiography[56] and its later history in *Technology Review* for January 1934. Richards was the seventh of the 15 students who entered M.I.T. when it opened in February 1865. He had intended to take mechanical engineering but changed to mining because, as he says bluntly, the professor of mechanical engineering was such a poor teacher. When, with five others, he completed the course in 1868 he was asked to remain as an assistant, and the subsequent development of the mining course coincides with Richards' own development. But the first planning for the school was done by W. B. Rogers, in collaboration with his brother Henry, who first suggested it in 1846. William Rogers was teaching at the University of Virginia until 1853, when he went to Boston, intending to settle there, complete his final report on the Geological Survey of Virginia, and engage in professional work. Henry Rogers left Boston for Scotland in 1858, having been appointed professor of geology in the University of Glasgow. William remained in Boston, doing professional work, publishing papers, and participating in the continuing movement for promoting natural and applied science.

The Back Bay, a shallow basin of salt water west of the peninsula on which Boston first developed, had been filled by the Commonwealth of Massachusetts, and the principal movement at that time was to persuade the State to devote at least a part of the area to educational purposes. Rogers wrote the "Memorial of the Associated Institutions of Art and Science" which was presented to the legislature in 1860, asking for a specified part of the total area and describing at considerable length the general purposes for which it would be used. He followed this, later in the year, with "Objects and Plan of an Institute of Technology," actually written by Rogers though submitted as the report of a committee of 19 of which he was chairman. This was published in 1860 and a revised version appeared in 1861. What concerns us is that the first plan was for a School of Industrial Science, with five subdivisions: design, mathematics, physics, chemistry, and geology. The text under geology says "systematic teachings in physical geology and mining, with so much of the general science as is important to illustrate the more practical branches of the subject." One can imagine he had one eye cocked at Harvard as he wrote it.

Rogers also wrote the report (March 19, 1861) of the Joint Standing Committee on Education of the Massachusetts House of Representatives (to which the Memorial had been referred) recommending the granting of the lands and also recommending that a petition for a charter for the Massachusetts Institute of Technology "empowering it to carry into effect the plan of a Society of Arts, a Museum of Arts, and a School of Industrial Science," be granted. The memorial says that the Boston Society of Natural History had "already received earnest intimations, conditional on this grant, of a municipal endowment to be devoted to the School of Industrial Science, and of a liberal appropriation from a different quarter for building purposes"; and they "agree to raise a sum of $100,000 for their appropriate purposes before entering on the granted land." The legislature granted both the land and the charter in 1861, and in 1863 voted three-tenths of the income from the Morrill Land Grant Act to M.I.T.

The Society of Arts of the Massachusetts Institute of Technology held its first public meeting on Dec. 17, 1862, but the

School of Industrial Science did not open to students until 1865, as Rogers had difficulty in raising the $100,000 on which the gift of the land was conditioned. Some time before December 1863, the 150 by 100-ft. Rogers building was started, but it was not finished and ready for occupancy until January 1866. In 1864 a 28-page pamphlet, "Scope and Plan of the School of Industrial Science of the Massachusetts Institute of Technology," was published, supplemented by a 10-page "Outline of Studies of the Department of Practical Geology, Mining, and Metallurgy." The interesting thing about the latter is the amount of space devoted to descriptions of proposed laboratories, almost a whole page to the laboratory for mining and metallurgy, and another page to "Visits and Excursions for Observation and Practice." This must be, I think, the first mention of laboratory instruction in connection with mining and metallurgical work in America.

The school finally opened, with 15 students* in attendance, on Feb. 20, 1865, in two rooms in the Mercantile Library. In the autumn, when there were 70 students in all the courses, they moved to Chauncey Street, and finally, in 1866, to the Rogers building. James D. Hague was announced in the first catalogue as professor of mining engineering, but apparently he never actually came to the school. Alfred D. Rockwell was called from Yale as professor of mining in 1867 and remained until 1873, when Richards was promoted to professor of mining engineering and head of the department. Charles W. Eliot (afterward president of Harvard) was professor of chemistry and metallurgy, but Richards says (p. 41), "We scarcely saw Eliot. On account of his wife's illness he was obliged to be abroad most of the time." John M. Ordway gave the metallurgical instruction for a long time, but his major interest was in industrial chemistry, and in 1883 Richards was made professor of both mining and metallurgy. In spite of the emphasis on differences from Harvard, the curricula seem to have been poorly organized at first and it was not until Richards (ref. 56, pp. 91–92) tackled them in the early seventies that they were systematized.

J. D. Runkle, who had been professor of mathematics and who succeeded Rogers as president in 1870, supplied the next impulse toward the development of mining and metallurgy instruction. He spent the summer of 1870 traveling through the West. Richards says (p. 65 of ref. 56): "His object was to visit as many mines and smelters as possible, to talk with owners and managers explaining about the new school, its purposes and methods, and rouse interest by asking for suggestions and help. He also interviewed mine owners and manufacturers of mining machinery."

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* Richards' autobiography, p. 88. The catalogue for 1865–66 indicates that 24 students had been in attendance at the previous session.

The next year he organized the first summer school of mining.* Taking with him J. M. Ordway, who taught metallurgy and industrial chemistry, and Richards, who had returned to M. I. T. in 1868 as assistant instructor in the chemical laboratory, and an unspecified number of students (apparently the trip was voluntary, not a course requirement), he visited the iron mines of Missouri, silver and gold mines in Colorado and Utah, and finally arrived in San Francisco. There they obtained a Hendy concentrator from the Joshua Hendy Machine Works, and a working model of a California stamp mill, an amalgamating pan, and a mercury settler from the Union Iron Works. These, with the several hundred sacks of ore they had obtained at the various mines visited, were sent to Boston as the initial equipment for the Institute's mining laboratory. Ordway, who had left the party in Colorado, was already back in Boston building assay furnaces, small reverberatory and blast furnaces, roasting furnaces, a lead-melting kettle and cupelling furnace, and other equipment for the metallurgical laboratory (pp. 69–70 of ref. 56).

Richards, who had been assisting in the chemical laboratory, took such an interest in the mining field work and showed so much energy that President Runkle put him in charge of setting up and operating the mining laboratory. His successive advances to the teaching of mineralogy and blowpipe analysis, the giving of the mining lectures, the development of his ore-dressing laboratory, and eventual direction of both the mining and metallurgical instruction, are told in interesting detail in his autobiography and need not be repeated. Rogers made the first plans for mineral industry instruction at M. I. T., Runkle gave it effective help when the initial impulse was weakening, and Richards took it up and developed it. It was not until 1876 that M. I. T.

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* This may have been suggested by the provisions of Senator Stewart's bill to create a National School of Mines. See p. 71, also pp. 120–122.

graduated more (8) men in mining than it had its first year,* and after that the number again declined for a time.

Washington and Lee

Washington and Lee, which dropped mining after 1875, can be passed over lightly. It had in 1865 large ambitions for training men to help bring about the economic recovery of the South, which were far beyond its practical means of realization. The professor of mathematics gave the instruction in civil engineering as well as mining. Its geographical situation, at Lexington, Va., was also against its development of mining instruction. The Virginia Polytechnic Institute (the land-grant college established at Blacksburg in 1872) was nearer the regions of mining importance. After it started† there was less reason for trying to develop mining instruction at Lexington, and the course was officially dropped in 1876, after having granted a total of eight mining degrees. In 1894 an attempt was made to revive it, with mining as an elective of the last two years of the civil engineering course, but no students ever elected this option, no professor of mining was ever appointed, and the attempt failed.

Lafayette

Whether it was Lafayette's visit to America that inspired the citizens of Easton, Pa., to attempt to start a college in 1824, or whether they, with practical psychology, utilized the enthusiasm he had evoked to promote their project, is not clear. A charter was obtained in 1826 and work began in a rented farmhouse in 1832. Perhaps because of its name, the first idea was to make it a military institute, but the first president insisted on manual training. Actually it soon developed into a classical college, especially after 1849, when the Presbyterian synod of Pennsylvania came to its rescue in financial difficulties. In the early 60's Ario Pardee, of Hazelton, gave the school $100,000 to establish a scientific course. The faculty of 9 in 1864–65 was increased to 18 in 1865–66. The classical tradition was still strong and the first three years of the new scientific curricula were so heavily loaded with ancient geography, Greek antiquities, Anglo Saxon, and courses in Biblical literature, that what we now consider basic engineering had to be crowded into the last year, along with the material pertinent to civil engineering, chemistry, or mining. But whatever its drawbacks, it was a definite curriculum leading to a degree in mining and, except for those at Columbia and Pennsylvania Polytechnic, was the only one offered in 1865–66.

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* The original charter of M.I.T. did not authorize it to grant degrees. It was amended in 1868 and thereafter the S.B. degree was given for a four-year curriculum.

† The Virginia Polytechnic Institute is described on p. 159. It gave some instruction in metallurgy, as a part of the chemistry course, from its earliest days.

The first graduate in mining was Michael S. Seip, 1870; in 1871 three degrees were awarded. In 1876 five men graduated in mining, but in no other year previous to 1890 were there more than three, and in 1881, 1888 and 1889 there were none. H. S. Osborn, who was appointed professor of mining and metallurgy in 1865, had taken his A.B. degree at the University of Pennsylvania in 1841 and gone abroad to study natural science at Bonn and London. Returning, he went to Union Theological Seminary and was ordained a Presbyterian minister in 1848. From 1848 to 1865 he served as a pastor of churches at various places, and was for a while professor of natural science at Roanoke College, Va. In 1869 he published a 972-page "Metallurgy of Iron and Steel," which was a skillful job of rewriting for the publishers of Frederick Overman's two books "Manufacture of Iron" (1849) and "Manufacture of Steel" (1851). In 1870 he left Lafayette to become professor of natural sciences at Miami University, which closed down in 1873. He kept on preaching, lecturing, and writing books on the Holy Land and mineral technology. In 1892, twenty years after leaving Lafayette, he published his immensely successful "The Prospectors Field Book and Guide," which went through eight more editions after his death that year. E. S. Moffat was appointed adjunct professor of mining and metallurgy at Lafayette in 1868, but left in 1873. Frederick Prime, Jr., was made professor of mining and metallurgy in 1870 and remained there till 1881. J. M. Silliman, who graduated in mining engineering at Rensselaer Polytechnic in 1870, went to Lafayette in 1871, where he had the title of professor of mining engineering until he died in 1896, but seems to have taught mostly mineralogy, economic geology, drawing, and descriptive geometry. Although after Prime left, in 1881, Silliman must have

John Markle Mining Building, Lafayette College.
Erected 1929. Houses mining, metallurgical engineering, and geology.

given all the instruction in mining, and also conducted summer mining-school work, his published work indicates that his greatest interest was in descriptive geometry. William S. Hall succeeded Silliman in charge of mining instruction and was in turn followed, about 1910, by William S. Marquard, a graduate of Ohio State.

Though Lafayette had continued to offer a mining curriculum ever since it first started, it had never had a large attendance. John Markle, who had graduated there in 1880, was keenly interested in it, and offered financial support that eventually amounted to a building and an endowment of $1,000,000. William B. Plank (E.M., Pennsylvania State, 1909) was appointed in 1920 to the professorship of mining, which had been vacant since 1917, and L. F. Witmer was made professor of metallurgy, a title that had not been used since Prime left in 1881. C. W. MacDougall was made assistant professor of mining in 1923; he was succeeded by A. H. Fay in 1929, and the latter was followed by J. W. Stewart in 1937. The school now offers four-year curricula leading to the B.S. degree in mining engineering (with options in engineering and administration) and in metallurgical engineering.

RENSSELAER

Rensselaer Polytechnic initiated a course in mining and metallurgy in 1867 with George W. Maynard as professor of mining and metallurgy. Maynard, after taking his A.B. at Columbia College in 1859, went abroad to study at Göttingen and Clausthal. Returning to the United States, he opened an engineering office and chemistry laboratory (Maynard and Tiemann) and also took an A.M. degree in chemistry at Columbia in 1864. Soon afterward he opened an assay office in Gilpin County, Colorado, but came back to New York in 1867 to take charge of a sulphuric acid plant on Staten Island. Going to Rensselaer in the autumn of 1867, he began with 10 students, who had already completed the first two years of the civil engineering course, and gave them two years work in mining, metallurgy, and assaying. Five men graduated as mining engineers in 1868, five in 1869, eight in 1870, and five in 1871, the year he resigned. Maynard said:[33] "The department was, for lack of money, discontinued in 1871." Possibly one can read between the lines of this that the salary was too small to induce Maynard to stay, while he recognized that one man could not permanently continue to give all the instruction in mining and metallurgy. Later he became interested in the Thomas process, established himself as a mining engineer and metallurgist in New York and became widely known. It is interesting to note that when he died, in 1913, most of his obituary notices referred to him as "the dean of American mining engineers" though he had never taken a mining engineer degree.

Lehigh

Lehigh was incorporated in 1866 and began work that autumn in a building on the 56-acre tract that Packer had given. Four-year courses were announced, of which the first two years were identical and the last two devoted to civil engineering, mechanical engineering, mining and metallurgy, analytical chemistry and general literature, respectively leading to corresponding degrees. The E.M. degree was given for the mining and metallurgy curriculum.* W. T. Roepper, professor of mineralogy and geology, appears in the first catalogue; Richard P. Rothwell, demonstrator of mining and metallurgy, appears in the 1869–71 catalogues; but no professors of engineering were appointed until 1871, when the half-million dollars promised by Packer became available. Benjamin W. Frazier was then made professor of mining and metallurgy; he also taught economic geology and his chief interest was in mineralogy. He continued in charge of mining and metallurgy until 1881, when he became professor of metallurgy and mineralogy and E. H. Williams, Jr. (who had graduated from the mining course in 1875) was made professor of mining and geology. The first E.M. degree was given in 1871 and the next in 1875; only six such degrees were awarded before 1880. From 1871 to 1892 tuition was free; possibly this is one reason for the unusual ratio between the total number of students and the number of graduates. There were 56 students enrolled in the mining course in 1887–88 but only three mining degrees were granted in 1888. Though three E.M. degrees were granted in 1882, the only other degrees given that year were one B.S. and four C.E. Probably it was difficult to secure from the tributary region students adequately prepared to carry an engineering curriculum to its completion.

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* After 1872 the degree of Metallurgist was offered for a metallurgy option, but none was ever granted; in 1881 this was changed to Bachelor of Metallurgy, and four such degrees were awarded in 1884.

National School of Mines

On Dec. 2, 1867, Senator William M. Stewart of Nevada introduced into the Congress of the United States, a bill (S. No. 156) proposing to allocate "the tax levied and collected upon gold and silver bullion in the States and Territories situated in whole or part west of the eastern base of the Rocky Mountains" . . . "as a special fund for the endowment and support of a school of mines, to be located on the line of the Pacific railroad, west of the Rocky mountains, as near as practicable to the centre of the Mining States and Territories." It was called up on Jan. 16, 1868, and Senator Stewart made a nine-page speech supporting it, in the course of which he said that the bullion tax was one-half of one per cent, and estimated that it would yield $250,000 during 1868. All of it was to be expended the first year for buildings and after that half of it was to be invested in Government securities, until the accumulation yielded enough income for operating expenses of the school, after which the tax was to be abolished. The bill provided that the professors, accompanied by their students, should make annual visits to the principal mining districts. Apparently the bill was referred to the Committee on Mines and Mining of the Senate, which reported it out on Feb. 20. There is no record of any hearing, or any further action on the bill.

In Rossiter W. Raymond's annual report as U. S. Commissioner of Mining Statistics for 1868 (published in 1869), there is a long section on the relation of governments to mining. About 35 pages of it is devoted to a description of European mining schools, ending in an argument for the establishment of a National School of Mines in the United States. There is no further reference to the subject that I can find, except S. B. Christy's argument against it in 1893 (see p. 131). Raymond's report for 1871, submitted in March 1872 and published in 1873, devoted 26 pages to American schools of mining and metallurgy, describing the curricula, faculty, and equipment at Columbia, Massachusetts Institute of Technology, Yale, Lafayette, Lehigh, Harvard, Rensselaer Polytechnic, University of Pennsylvania, Missouri (Rolla), Washington University, and, oddly enough, Stevens Institute, which never intended to give mining instruction and apparently was included only because Raymond had recently published a description of it in the *Engineering and Mining Journal.* Reference is also made to "an inchoate school in Colorado" and "a promising department for this subject in California." He does not mention the Polytechnic College of Pennsylvania, the University of Michigan, Washington and Lee, where mineral instruction was already fading, nor the Universities of Wisconsin and Illinois, where it was just starting.

WISCONSIN

The University of Wisconsin had its origin in an act of the territorial legislature, passed in December 1837, providing for "the University of the Territory of Wisconsin" to be situated at Madison. Except for an act of Congress conveying to it two townships of public land, nothing further was done for 10 years. Meanwhile Wisconsin had been admitted as a state and in 1848 its legislature incorporated the State University. The first bachelor's degree was conferred in 1854 on two students. The story of its growth between that time and 1870, when mining instruction was instituted, can be found in J. F. A. Pyre's history of the institution.[49]

Roland Duer Irving, who had taken the E.M. degree at Columbia in 1869 (A.M., 1870; Ph.D., 1879), was appointed professor of geology, mining, and metallurgy at Wisconsin in 1870, and established a department of mining and metallurgy there the following June. Mining was not yet important in Wisconsin and only a few students appeared. The first mining degrees were given in 1876 to two men. The space available, in the basement of Main Hall, was inadequate, and Irving's interests turned mainly toward geology. He was one of the pioneers in the study of rocks under the petrographic microscope, and one of the great scholars of the early Wisconsin faculty. The most notable event of that early period was that Charles R. Van Hise, who took the B.S. degree in mining and metallurgy at Wisconsin in 1879, was appointed assistant in mining, then made instructor in metallurgy, and finally appointed professor of metallurgy: Irving becoming professor of geology alone. Van Hise worked with Irving and became even more distinguished than his superior in the application of microscopic petrology to the solution of geologic problems. Their various monographs on the geology of the Lake Superior region are too well known to need description here.

When Irving died, in 1888, Van Hise's title was changed to professor of mineralogy and petrography,* and Floyd Davis appears in the announcement for one year as acting professor of metallurgy. In 1889 the University was reorganized in four colleges—Letters and Science, Agriculture, Engineering, and Laws. The mining and metallurgical instruction was assigned to the College of Engineering. No one seems to have been appointed to teach either subject and the last mining degree was given in 1889; twelve had been conferred between 1876 and 1889. Between 1890 and 1908 no definite curricula in these subjects were offered, though the announcements usually indicate that the degrees of B.S. in mining engineering for four years' work, and of E.M. for five years' work, might be attained. The revival of mining and metallurgical engineering instruction after 1908 is recorded on p. 161.

Though after 1889 geology was in the College of Letters and Science, and mining was in the College of Engineering, Van Hise retained a broad interest in economic geology in its widest applications. After he became president of the University his associates and successors, Charles K. Leith, W. J. Mead, and others, continued active in the field of economic geology, both within the University and in professional consulting work, particularly in relation to ore deposits in the pre-Cambrian. A considerable range of publications has resulted from this work. Leith's course in the economic aspects of geology (as distinguished from the geology of ore bodies), which he instituted in 1927, was probably the first in any American university to treat broadly of minerals in their economic, political, and social relationships.

It has been pointed out in preceding pages that geology was taught in mining schools as both a pure science and an applied science; in the gradual development of institutions geology, in some places, tended to develop chiefly as pure science. Wisconsin is an excellent example of a geology department that not only retained its interest in the practical applications of the science but widened them so as to cover the social and political aspects of mineral enterprise.

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* Van Hise received the first Ph.D. degree conferred by the University of Wisconsin, in 1892, and was made head of the department of geology the same year. In 1903 he became president of the University and held that office till his death in 1918.

Washington University

At Washington University, St. Louis, which was chartered in 1853, the Columbia influence is more distinct. It had opened an evening Polytechnic Institute in 1854, and began offering regular courses in civil and mechanical engineering and chemistry about 1867. In March 1871, Thomas Allen, a Washington alumnus, offered to give the income of $40,000 at 7 per cent for 5 years to establish a professorship in mining and metallurgy. William B. Potter, who had graduated from the Columbia School of Mines in 1869 and had since been assistant in the geology department and on the Ohio Geological Survey, was appointed to this chair in August of the same year. The first E.M. degree was given in 1874. The parent institution was then small and weak (there was a total enrollment of only 18 in the Polytechnic department in 1871) and the relatively small number of mining degrees given in succeeding years actually represents considerable success; the four mining graduates in 1883 comprise all the degrees given by the School of Engineering that year. One of them was Pope Yeatman, who may be mentioned by name to illustrate that while the number of graduates was never large a surprisingly large proportion quickly attained positions of importance; this was especially true in smelter operation. In 1883 H. A. Wheeler, who had graduated at Columbia School of Mines in 1880, was made adjunct professor of mining. Gustav Hambach was adjunct professor of geology, but Potter and Wheeler must have taught economic geology as well as mining and metallurgy.

In 1893, Potter, who had participated in organizing the St. Louis Sampling and Testing Works in 1888, resigned his professorship and thereafter gave his whole time to the sampling business. Wheeler, who had meanwhile become connected with the Missouri Geological Survey, left the following year. As no one was appointed to fill the vacancies thus created the mining curriculum died a natural death, though H. A. Hunicke, who received the E.M. degree in 1882 and thereafter taught some of the courses in geology, crystallography, and mineralogy, continued to teach those subjects for some years more. No mining degrees were given after 1894.

ILLINOIS

Meanwhile the Colorado School of Mines had been established in 1868, and the School of Mines of the University of Missouri at Rolla had graduated one man in mining in 1874, but it seems wisest to postpone discussion of State-supported mining schools until the next chapter, where their period of marked development, mostly in the late eighties and early nineties, can be better covered.

Illinois was the last state of the Northwest Territory, and the last one of the Middle West, to found a State university. It is unnecessary to review its educational history here, since it is easily available,[41] but it should be mentioned that there was great conflict over the situation of the institution and when, as Illinois Industrial University, it was started at Urbana in 1867, there was much feeling elsewhere in the state. Though Major J. W. Powell was selected as its first professor of geology, unfortunately he never went there to teach.

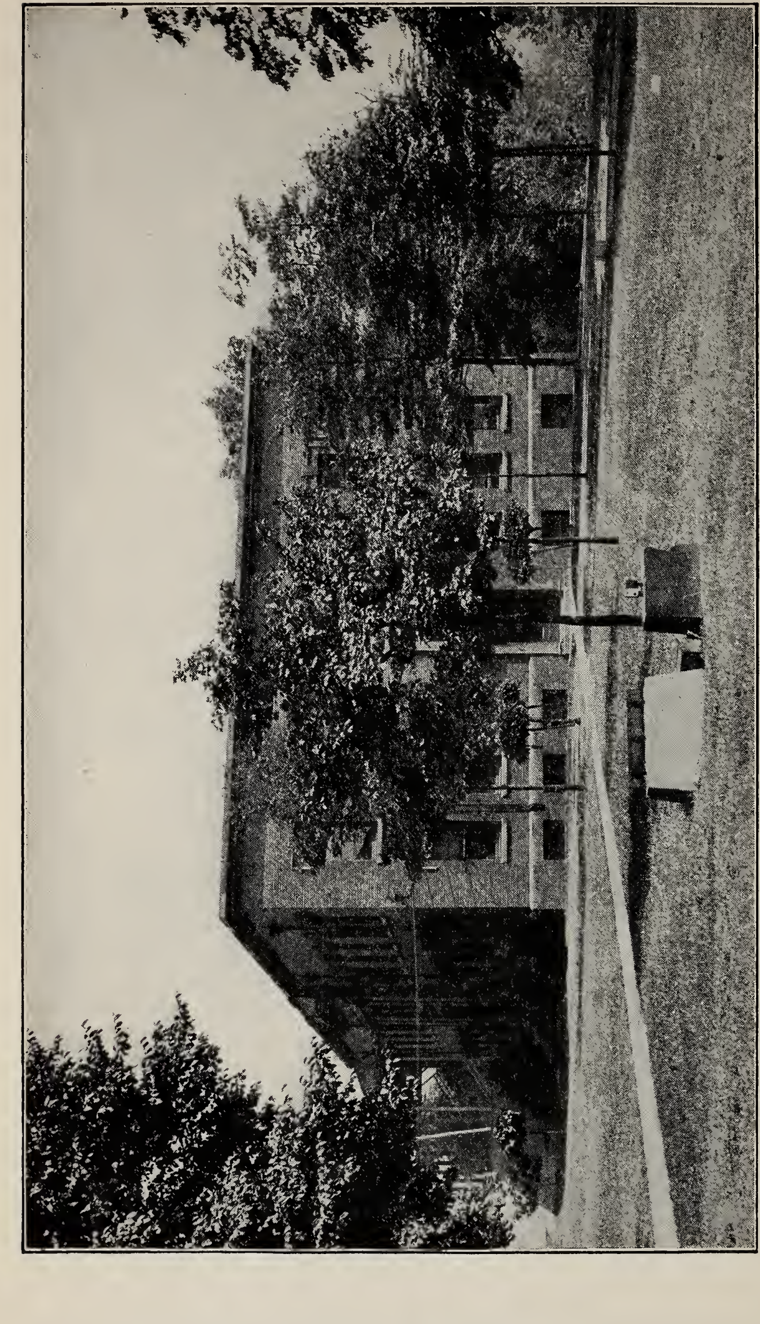
As early as the seventies it was organized into four or more colleges, each made up of two or more schools. The College of Engineering in 1873 had four schools—mechanical engineering, civil engineering, mining engineering, and architecture. But all the faculty and assistants of that year are listed on a single page in the catalogue, and no name appears in the field of mining and metallurgy. Though a sketchy four-year mining curriculum appears in the catalogues of the seventies, the first three years were identical with the civil engineering course, except that mineralogy was substituted for analytical mechanics in the third year. Some specific mining and metallurgical instruction was scheduled for the fourth year, evidently given by S. W. Robinson, who was instructor in mining, as well as professor of mechanical science and engineering. One student took the mining degree in 1878, three in 1879, one in 1880; then none until 1887, when there was one. Theodore B. Comstock went to Illinois as professor of mining engineering and physics in 1885 and remained until 1889, when he left to become State Geologist of Texas and later president of the University of Arizona. The current catalogues give little indication as to the instruction he gave, but an early alumnus of Illinois tells me it was well planned and excellent. After he left the vacancy was not filled for two years, but in 1891, W. J. Baldwin, who had graduated in mining at the University of Michigan and taught for a couple of years at the School of Mines at Houghton, was secured to give instruction in coal mining, mine surveying, and assaying. His appointment was not renewed after 1892–93, no freshmen having entered the mining curriculum. The announcement of 1892–93 is the last one that lists mining engineering as a department of the School of Engineering. How it was revived in 1910 will be told in a later chapter. Wisconsin, Illinois, Tennessee, and Wyoming were the only State-supported schools that initiated mining instruction and later dropped it. Illinois and Wisconsin were the only ones that again resumed it.

Vanderbilt University

Vanderbilt University, Nashville, Tenn., began work in October 1875. Previous attempts of the governing bodies of the Methodist Episcopal Church South to establish a university in that region had come to nothing for lack of money, but a gift of $500,000 from Cornelius Vanderbilt (followed by an additional $200,000) enabled a start to be made. As first organized it consisted of four departments: Law, Medical and Philosophy, Science, and Literature. The 1876–77 announcement says that the law and medical departments were already in successful operation "and, as soon as their means will allow, they will establish, under special professors, Schools of Civil Engineering, Mining Engineering, and the Useful and Fine Arts." The announcement is not quite clear, but apparently the civil engineer degree was to be awarded to those who had completed the college course "and, in addition, the special course prescribed in the School of Engineering." The mining engineer degree was to be awarded for one more year of work to those who had taken the civil engineer course. Alexander Winchell was the professor of geology, an adjunct professor of engineering was appointed in 1878, but Winchell left the same year. The statement regarding the mining engineer degree disappears from the announcement after 1879–80 and nothing more is said about it until 1887–88, when engineering was made a separate department, and curricula in civil, mechanical, and mining engineering were announced. These consisted of three years of academic work, a fourth year of professional work for the bachelor's degree, and a fifth year for the engineer degree. A. C. Campbell was appointed instructor in mining and metallurgy and W. L. Dudley, who had been professor of chemistry, had metallurgy added to his title. One student was enrolled in mining each year until 1895–96, when there were none. Only one mining degree was awarded in this period, though announcements continued to carry the statement that the engineering department consisted of the four Schools of Civil, Mechanical, Mining and Electrical Engineering, until 1909–10, after which mining disappeared, chemical engineering having meanwhile been introduced. Apparently all the metallurgical instruction was given in the chemistry department and the professor of mechanical engineering taught the mining courses, in the latter part of the period. Whether students were not attracted to the school because no really adequate instruction in mining and metallurgy was offered, or whether it was not offered because few students came, is difficult to say. Probably there was but little interest in mining as a career in the region tributary to the school.

Case School

Case School of Applied Science was endowed by Leonard Case in 1877, who set aside some two million dollars worth of Cleveland real estate to establish a school "to teach mathematics, physics, engineering, mechanical and civil, chemistry, geology, mining and metallurgy, natural history, languages" and such other subjects as the trustees should consider necessary. A year after his death in 1880, the School was opened in his own home. It moved in 1885 to a new building opposite Wade Park, which burned down in 1886, creating difficulties, as only the income of the endowment could be used to provide buildings; growth therefore was necessarily slow. By 1892 it was offering four-year curricula in civil, mechanical, electrical, and mining engineering, physics,



Mining and Metallurgical Laboratory, Case School of Applied Science.
Gift of John D. Rockefeller. Erected in 1906.

chemistry, architecture, and general science, all leading to a B.S. degree. The tuition fee was $100 per year, and the appropriate engineering degree was awarded for a fifth year of study. The six mining students enrolled in 1894–95 increased to 13 in 1896–97; by that time it had awarded eight mining degrees. In the faculty of 20 listed in 1893–94, there was no professor of mining, and metallurgy was covered by A. W. Smith, who was also assistant professor of analytical chemistry.

In 1906, Prof. Charles S. Howe (mathematics and astronomy), who was greatly interested in mining and metallurgy through having been employed in an assay office in Arizona in his youth, secured from John D. Rockefeller funds to construct a mining building as well as one for physics. Professor Smith continued in charge of both mining and metallurgical instruction until 1911, when Charles H. Fulton (E.M. Columbia, 1897) was called from the presidency of South Dakota School of Mines to be professor of mining and metallurgy, Smith becoming head of the department of chemistry. At the same time, J. Burns Read (B.S., S.D., 1906; E.M., 1909) was appointed assistant professor in mining, and Zay Jeffries (B.S., S.D., 1910) was made instructor in mining and metallurgy. Jeffries' major interest was in metallurgy, and in 1916 he left to become director of research for the Aluminum Casting Co.; Read left in 1919 to become assistant professor of mining at the University of Illinois. Fulton left in 1920 to become director of the Missouri School of Mines and was succeeded by Herbert M. Boylston (B.S. Harvard, 1903; A.M. 1905), who had been instructor in mining and metallurgy at Harvard since 1906. At the same time Kenneth H. Donaldson (E.M. Columbia, 1911) was appointed assistant professor of mining engineering.

When Boylston died, in 1939, Donaldson, now professor of mineral industry, became head of the metallurgical engineering department, local industrial interest being in ferrous and physical metallurgy rather than in mining. G. M. Cover and George Sachs are associate professors, and H. A. Schwartz and W. P. Sykes professorial lecturers in metallurgy; Thomas R. Graham, E. G. Leatham, and W. W. Culbertson are instructors in metallurgy. A four-year curriculum is offered leading to the B.S. degree in metallurgy (33 were awarded in 1940). The curriculum leading to the B.S. degree in mining engineering was dropped in 1929, but the E.M. degrees (and Met. E.) are occasionally awarded to graduates of earlier years who have been engaged in responsible professional work for not less than three years and who submit a satisfactory thesis. M.S. and Ph.D. degrees in metallurgy are awarded under the usual conditions.

Chapter 7

THE RISE OF THE STATE SCHOOLS

ANY discussion of State-supported schools of mining and metallurgy needs to be prefaced by a definition, since the first school to offer a mining curriculum, the Pennsylvania Polytechnic College, was established by a grant from the State. But, so far as can be determined, it received no further State support. It would be tiresome to go into precise details, and it will be enough to stipulate that by State schools are meant those which derive their main financial support from regular appropriations made by a State legislature. The University of Michigan was the first of these to offer a mineral industry curriculum; its story, as well as those of Wisconsin and Illinois, has been related in the preceding chapter.* Arranging the others in chronological order involves making a decision as to what weight to attach to plans for giving instruction, as contrasted with its effective initiation. This may appropriately be illustrated by the history of mineral industry education in California.

California

Among those who came to California in 1849 and the following years were many New Englanders who had a keen interest in education. Some of them, mostly Congregationalists and Presbyterians, sought to establish a school of higher education around San Francisco Bay and eventually succeeded in opening the "Scientific and Classical School at Contra Costa" in Oakland, at Broadway and 5th St., on June 20, 1853. This prospered so well that it was chartered by the State as the "College of California" on April, 13, 1855. Developing so rapidly that its quarters became cramped, in 1864 it not only bought a tract of land in Berkeley, where the University of California now stands, but also started a "Mining and Agricultural College" in San Francisco the same year, with William P. Blake as director.

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* This chapter only covers State schools established prior to 1890; those established later will be found in subsequent chapters, in the chronological order of their establishment.

William P. Blake had graduated in chemistry from Sheffield Scientific School in 1852. For a while chemist and mineralogist for the New Jersey Zinc Co., and in 1854–56 one of the geologists for the Pacific Railroad Surveys, he started the *Mining Magazine* in New York in 1859. It failed in 1860 and in 1861 he went to Japan to help organize a scientific school, in which he taught geology and mineralogy until 1863. Returning to California, he was appointed mineralogist of the State Board of Agriculture in 1864 and also became professor of geology and mineralogy as well as director of the school just mentioned. There seems to be no record of where the school was, of its equipment, or of how many students attended it. Gardner F. Williams graduated from the College of California in 1865, but I have been unable to establish that he attended its "Mining College" in San Francisco. What little information is now available about this school pertains chiefly to the struggle to obtain for it the Morrill Act subsidy. This was settled in 1868 by the College of California volunteering to give the land it owned in Berkeley to the State University that had been created by the legislature in 1865, but for which no site had yet been chosen. The denominational college was merged with the University as its collegiate department and went out of existence as a separate institution. Meanwhile, in 1867, Blake had been appointed one of the California Commissioners to the Paris Exposition, and thereafter had probably been unable to give any time to the school.*

The story of the development of the University of California has been told in detail by William Carey Jones[29] and by W. W. Ferrier[22] and only the part of its story that bears directly on mineral industry education need be repeated here. On April 22, 1863, the legislature created a commission composed of J. D.

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* Blake was offered the presidency of South Dakota School of Mines in 1885, but declined it. After spending many years in other lines of work he returned to teaching in 1895, at the age of 70, becoming professor of geology and mining and director of the School of Mines at Tucson, Ariz. He remained there for 10 years, and eventually died from pneumonia contracted while receiving an honorary degree from the University of California in 1910.

Whitney (then the State Geologist), John Swett, Superintendent of Public Instruction, and J. F. Houghton, to investigate and report by December "on the feasibility of establishing a State University, embracing an agricultural college, a School of Mines, and a museum including the geological collection of the State." They reported favorably, but naturally Whitney thought that a museum for preserving and displaying the geological material was what was most needed, so the draft of the act they submitted provided for the immediate establishment of the museum in San Francisco, and only for the submitting by December 1865 "a detailed plan of organization of a State Polytechnic School in connection with the State Museum." This report is interesting reading, for it sets forth that there was then not anywhere in the United States an institution "devoted to mining and allied branches," nor a professor of mining in any institution, and argues that since there were already "several colleges and schools calling themselves colleges" in operation in California, which had been started by religious denominations, it would be more polite to not invade the field of collegiate instruction but to start a "School of Science and Art," apparently of the general type of Rensselaer Polytechnic, after the Museum was a going concern.

This report was not very well received and meanwhile pressure grew for the establishment of an agricultural school, since the Morrill Act subsidy from the Federal Government would soon become available, and the College of California was endeavoring to get it. In the spring of 1865 the legislature passed a bill establishing an "agricultural, mining, and mechanical arts college," but educational opinion was against it, one of the members of the legislature being quoted as saying that it would merely create a large board of officers who would act like a set of leeches on the state treasury, and that such institutions had better be left in private hands. For some time no decision was made as to where to establish it.

The history of the contest for the Morrill Act subsidy, which was ended in 1868 by the donating of the site of the College of California, in Berkeley, to the State and the merging of the College of California into the State University as its collegiate department, is given in detail by Ferrier[22] and need not be repeated here. The new State institution began work on the old denominational site in Oakland on Sept. 23, 1869, with Robert A. Fisher as professor of chemistry, mining, and metallurgy, and Joseph LeConte as professor of geology. It had 38 students at first, and it continued its work there until 1873, while the new buildings were being built at Berkeley. The first degrees were granted July 20, 1870; three B.A. degrees and one M.A. awarded to a graduate of the College of California.

I can find no record that any mining degrees were ever given by the College of California, and the first mining graduate of the University of California was in 1874. That same year William Ashburner, who had been Whitney's assistant in the State Geological Survey and was then in private practice in San Francisco, was appointed professor of mining and metallurgy. In a short time his private practice so increased that he was unable to give any time to the school. George F. Becker, who was lecturer in metallurgy,* carried on the work of the School until 1876. There was no one with the title of professor of mining or metallurgy from 1876 until S. B. Christy (who had graduated at California in 1874 and was immediately appointed assistant in chemistry at $600 per year) became professor of mining and metallurgy in 1885.

Between 1893 and 1903 the registration of the mining college increased tenfold;[22] it constituted 4 per cent of the total University enrollment in 1893 and 11 per cent of the enrollment in 1903. At that time it claimed to be "without doubt the largest mining college in the world,"[8,47,67] with a total enrollment, including graduate students, of over 300. Only one four-year curriculum was offered, two years being devoted to fundamentals and two years to technical subjects. The rapid increase in interest in this curriculum was doubtless due to the same forces that were causing institutions throughout the country to begin to offer mineral industry instruction during this same period, but possibly it may have had local and personal influences as well. Charles Butters, who graduated at U. C. in 1879 and had had a varied experience throughout the United States, mostly in gold metallurgy, in 1889 went out to South Africa (having been recommended by Christy) as assistant to Hennen Jennings, then consulting engineer to H. Eckstein & Co. Butters had had much experience with chlorination plants, and he built a successful one for the Robinson, the first of its kind in South Africa.

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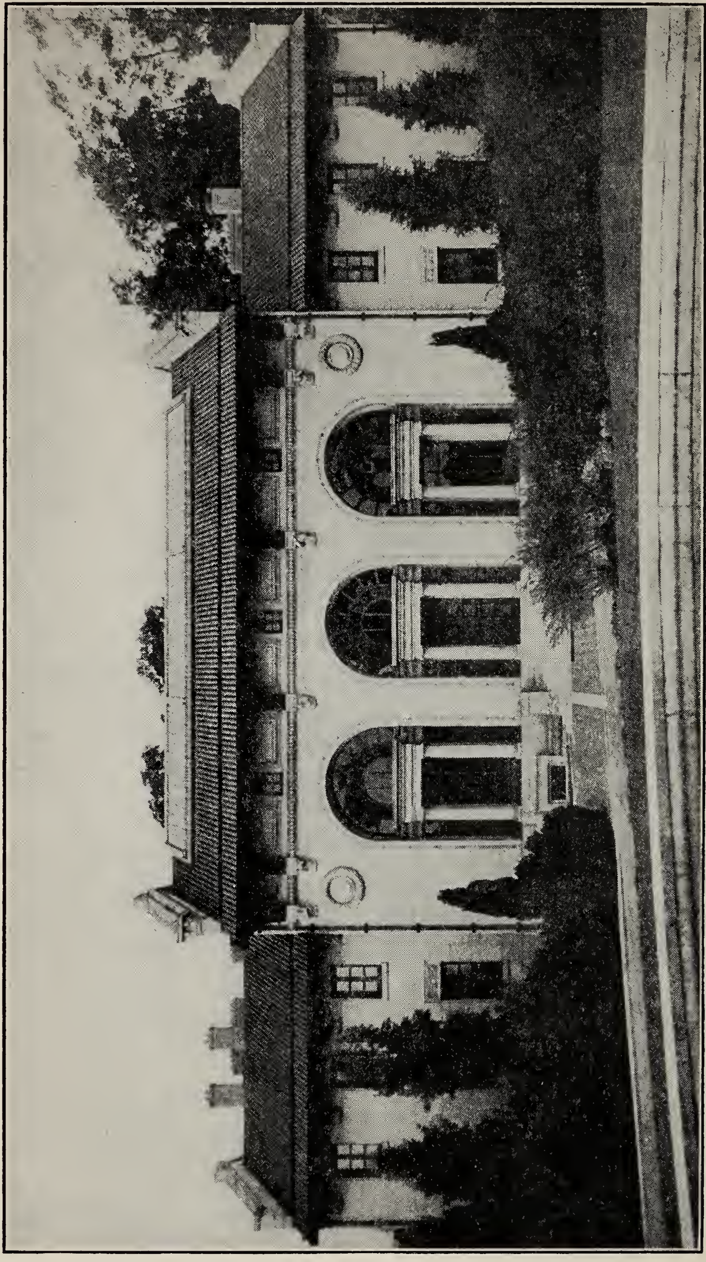
* Becker had taken his Ph.D. at Heidelberg in 1869, in mathematics and chemistry. Returning to America he worked for a steel company at Joliet, Ill., in 1872–73. Going to California (partly on account of his health) he was appointed lecturer in metallurgy at the University of California. While there he met Clarence King and was given an appointment to the U. S. Geological Survey, in which he made his subsequent career as geologist and physicist.

The patent litigation over their cyanide process had recently been decided in favor of MacArthur and Forrest, and Alfred James, the pioneer in the introduction of that process in South Africa (who had been working on the development of the process for two years), made a successful demonstration run of it at the Salisbury early in 1890. Jennings and Butters were convinced that it would displace chlorination, and Butters was instructed to design a cyanide plant to treat the residues from the Robinson chlorination plant. After eight years of successful experience on the Rand, Butters organized the firm of H. Butters & Co., Ltd., in London, and returned to the United States, having bought the San Sebastian mine in Salvador. The part Butters played in the development of the cyanide process, especially in filtration, is too well known to need repetition. That the technical and financial success of Butters, and of such other California graduates as Gardner F. Williams (1865), Fred W. Bradley (1884), Charles W. Merrill (1891), Philip R. Bradley (1896), and W. W. Mein and E. L. Oliver (1900), was a large factor in stimulating the growth of enrollment in the mining course at California naturally cannot be proved, but it seems quite probable.

Unfortunately for the boast as to the large enrollment there, in 1903–4 it immediately began to decline, continued to do so, and by 1915 was less than a third of what it had been 12 years earlier, in spite of the greatly improved facilities that meanwhile had been provided for it. As early as 1896 Mrs. Hearst had suggested to the Regents a plan for the development of the campus, and the first building completed under the plan, an imposing and costly granite memorial to her husband, dedicated in August 1907, was for the College of Mining, which had been elevated to that status in the University organization, with Christy as dean. Annual gold production in California had amounted to over eighty million dollars in 1852, declined to a little over eleven million in 1889, and



College of Mining, University of California. Hearst Memorial Building, erected 1907.

had again increased to seventeen million in 1901 and over twenty-two million in 1915. But the increase between these two latter years was due to the recovery from dredging, the yield from lode mines decreased from thirteen to eleven millions. It seems probable that in spite of the personal success of many California graduates in the gold country, it did not offer adequate vocational opportunity for so many men as were swelling the enrollment between 1893 and 1904.

Professor Christy, whose major technical interest had always been in gold metallurgy, died in 1914, and for the next two years, 1914–16, Andrew C. Lawson, head of the geology department, served as dean. Under his leadership steps were at once initiated to provide four different curricula leading to the B.S. degree; in mining, metallurgy, economic geology, and petroleum engineering, respectively. These had a uniform first year, some differentiation in the second, and marked differentiation in the third and fourth, with a total of 139 units of work. Much interest developed in the petroleum engineering curriculum (its development is described in greater detail on p. 192) and by 1922 it was attracting nearly one third of the students registered in the school.

Frank H. Probert (Royal School of Mines, 1896) who had had no teaching experience but a wide range of it in connection with the copper industry, and who had been a consulting engineer in Los Angeles since 1903, was made dean of the College of Mining in 1916. After the World War there was a sharp recovery in enrollment, the registration in 1919–20 being more than twice that in 1915–16. The major interest at first continued to be in the mining curriculum, almost two thirds the 1921–22 registration being in it. The proportions have since been reversed, the registration statistics for August 1940 being: petroleum engineering, 49.8 per cent; mining, 36.7 per cent; metallurgy, 8.0 per cent; and economic geology, 5.5 per cent.

Ernest A. Hersam (S.B., M.I.T.) was appointed assistant in mining in 1892, made instructor in metallurgy in 1894, became professor of metallurgy in 1923, and emeritus in 1938. Walter S. Weeks (A.B. Harvard, 1906; B.S., 1907, M.E., 1909) was appointed associate professor of mining in 1915, and became full professor in 1928. Lester C. Uren (B.S. California, 1911) was appointed research assistant in mining in 1912, and rapidly advanced through successive grades to professor of petroleum engineering. L. H. Duschak (A.B. Michigan, 1904; M.A., Ph.D., Princeton, 1908) who had been on the staff of the U. S. Bureau of Mines since 1913, and a lecturer at Berkeley since 1922, was made professor of metallurgy in 1938. A. J. Carlson (C.E. Minnesota, 1916; Ph.D. California, 1929) was made associate professor of petroleum engineering in 1930. Walter S. Morley (B.S.) was for many years associate professor of metallurgy, but became emeritus in 1941. Probert died in 1940, and Donald H. McLaughlin, who had been professor of mining at Harvard, was made dean of mining and also engineering in 1941. The total number of graduates from the College of Mining of the University of California is reported as 1244.

Colorado

There is no doubt, however, as to which was the first State mining school established as a separate institution.* The Colorado School of Mines, oddly enough, also owes its beginnings to a denominational college. George M. Randall, missionary bishop of the Episcopal Church for Colorado, arrived in Denver in 1866, and seems to have been as much disturbed by the mental state of the pioneers as by their morals. He made plans for a university, to include a School of Mines, and secured money for the purpose from George W. Jarvis, of Boston. Construction began in August 1869 but before it was completed the building was destroyed by a windstorm. In January 1870, the Colorado territorial legislature passed an act appropriating $3,872.45, which had been "derived from the sale of school mining claims," for "erecting and furnishing a brick building for the use of a School of Mines to be connected with and form part of Jarvis Hall, a collegiate institution located in Golden City."

Apparently the school was started at Golden because Charles C. Welch gave land there for the purpose. The action of the legislature in appropriating money for a building on privately owned land might have created later difficulties, but by 1874 pressure on the Episcopal Church to transfer its educational activities to Denver had become so strong that it was clear to the people of Golden that it would be necessary to have the Territory take it over, or else have it moved. C. C. Welch, who had given the land, introduced a bill into the legislature to accept a deed to the Territory, creating a Board of Trustees and appropriating $5000 for the support of the School.

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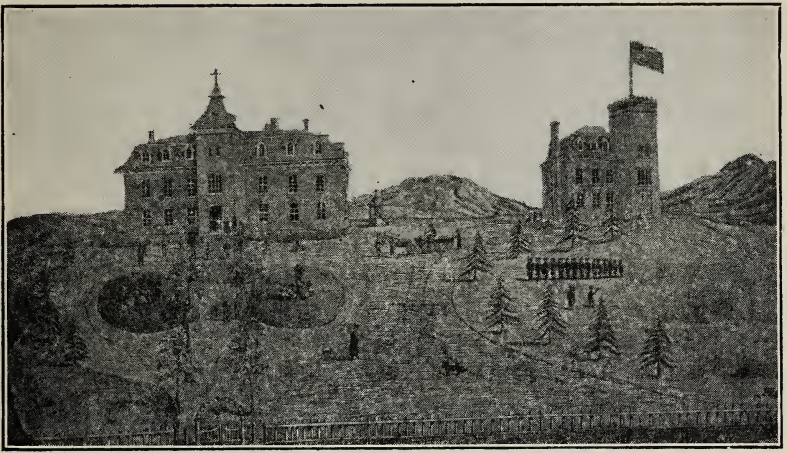
* The School of Mines, Rolla, Mo., though physically separated from the State University, was from the first regarded as a subdivision of it.



Jarvis Hall and Colorado School of Mines.
An early pencil sketch.

Meanwhile mining instruction had been organized in 1873 with E. J. Mallet, Jr., as dean and professor of metallurgy and chemistry; William West (superintendent of the smelter at Golden) as lecturer in metallurgy; E. L. Berthoud teaching geology and civil engineering; two clergymen teaching mathematics and Spanish, and Capt. George West, military science and tactics. The latter was an odd subject for a religious school; perhaps it was a concession to the official support. The catalogue for 1874 shows Richard Pearce as responsible for theoretical and practical metallurgy, Julius Pohle for mechanical preparation of ores, and Arthur Lakes for free-hand and mechanical drawing. Francis Schmidt taught mathematics, German and Spanish, the clergymen having withdrawn. It will be at once noticed that most of the staff were European born and trained.

Early in 1875 Mallet resigned and made an attempt to start a rival mining school in Denver, in Guard's Opera House, with himself as president. There is a printed "First Report" of this school but it seems to have had no other real existence.

Gregory Board, a graduate of the Royal School of Mines, London, succeeded Mallet at the Colorado School of Mines in 1876* and was in turn succeeded by Milton Moss, who had taken his Ph.D. at Heidelberg and studied mining at Clausthal. In 1880 Albert C. Hale, who also had taken a Ph.D. at Heidelberg, became the first president of the school by act of the legislature, and Lakes became professor of geology, the only one left of the original faculty. During all this time the school seems to have been well equipped for the time, for laboratory and field work, but apparently had difficulty in securing students who were adequately prepared to undertake work of collegiate grade. The first formal commencement was held in May 1883, with only two graduates, though E. C. Van Diest had been granted the E.M. degree in 1882. The 1882–83 catalogue shows one senior, 22 freshmen, and 57 special students. The 1890–91 catalogue lists one E.M., one C.E., and two B.S. degrees as having been given "since issue of last catalogue."† The 1891–92 catalogue announces a course in electrical engineering. Wadsworth's table[63] indicates that the total enrollment declined to 23 in 1884–85, and thereafter increased slowly but steadily to 161 in 1896–97. There is no way of ascertaining what proportion of this total was in the mining and metallurgical department, as the catalogues list students alphabetically without showing their year or curricula. It is probable that the original condition, of a heavy mortality beyond the freshman year, and having a large proportion of special students, long persisted.

The legislature in 1881 voted to grant one-fifth of a mill of the State tax to the support of the school. Regis Chauvenet, who had taken an A.B. at Washington University in 1862, an A.M. there in 1864, and a B.S. at Harvard in 1867, and was then chemist to the Missouri Geological Survey, was appointed president and professor of chemistry and metallurgy in 1883 and continued in office till 1902. He ushered in a period of steady growth. Charles S. Palmer was president in 1902–3. He was succeeded by Victor C. Alderson (A.B. Harvard, 1885) dean of Armour Institute, who reorganized the faculty, bringing Frank W. Traphagen (Ph.D. Columbia, 1883) from Montana as a professor of metallurgy in 1903, and securing Lewis E. Young (B.S. Penn State; E.M. Iowa, 1904) who had been assistant professor at Iowa State, as professor of mining. His presidency began an era of material expansion, the School began to attract gifts, Stratton Hall was erected in 1902 and Simon Guggenheim, then a candidate for U. S. Senator, in 1906 gave what until recently was the main building. A gymnasium was built in 1908 and the experimental milling plant in 1912. This serves a double purpose—to familiarize students with metallurgical processes and to provide facilities for testing ores to determine the best process. Its staff assists and cooperates with mineral enterprises. It was supported by biennial State appropriations until 1927, when a permanent State levy was granted.

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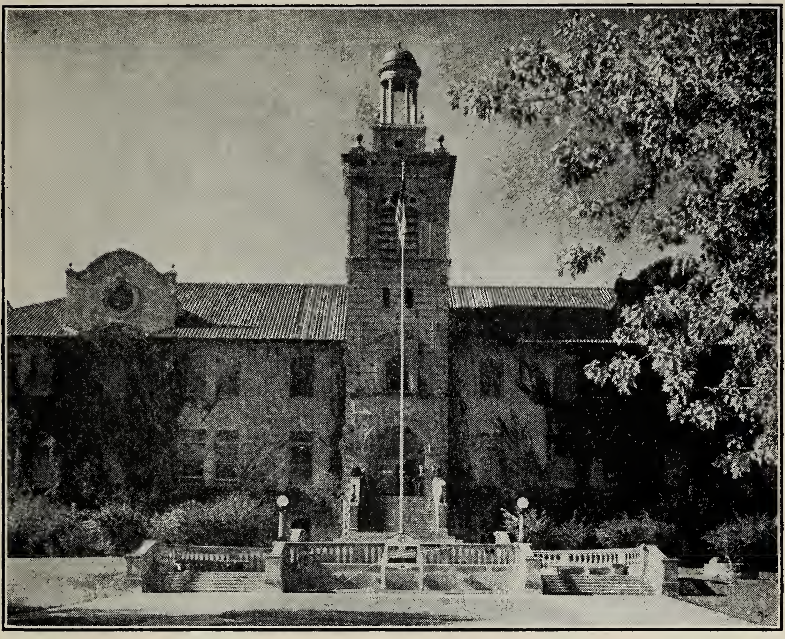
* W. A. H. Loveland, president of the Board of Trustees, was in charge in the interim.

† Wellington's list[3] shows one mining degree given each year in 1882, 1883, and 1885; four in 1886; six in 1888; and two in 1890.



Guggenheim Hall, Colorado School of Mines. Erected 1906.

William G. Haldane (B.S. Case, 1900) who had been associate professor of metallurgy and manager of the experimental mill, became acting president in 1913. He was succeeded by William B. Phillips (Ph.D. Univ. N. C., 1883), who had been director of the University of Texas Geological Survey 1901–5 and was president 1914–16. The latter was followed in 1916 by H. C. Parmalee (B.S. 1897, A.M. 1899, University of Nebraska) then western editor of *Metallurgical and Chemical Engineering.* Alderson returned to the presidency in 1917 and remained until 1925.

Melville F. Coolbaugh (B.S. Colorado College, 1902; M.A., Columbia, 1905) who had been professor of chemistry there in 1917–18, became president in 1925, initiating a third period of development. The faculty now numbers 84. It grants the degrees of engineer of mines, metallurgical engineer, geological engineer, and petroleum engineer for four-year curricula (the only school in the United States that does this) and also grants master's and doctor's degrees in these same fields. Its charter permits it to grant any degree appropriate to the courses of study pursued, but it has steadily confined itself to the field of mineral industry. Altogether, it has granted 2615 degrees, of which 46 were honorary. The enrollment in 1940 was 803, and nearly 8000 students have attended the school since it was founded. It has an engineering unit of the R.O.T.C. Special and part-time students are no longer admitted. The school operates the Edgar mine, at Idaho Springs, as a working mining and surveying laboratory and has a geological and petroleum field-work camp at Wild Horse Park, 15 miles northwest of Pueblo. In 1936 the mining building was remodeled to provide more adequate classrooms, laboratories, and offices. In 1939 Berthoud Hall was completed, to house the departments of geology, geophysics, and the mineral industry museum, at a cost of more than a half-million dollars. A housing project to accommodate instructors and married students, completed in 1940, consists of seven houses and twenty-four apartments.

MISSOURI

The Missouri School of Mines was born out of conflict. Its detailed history has been related by C. V. Mann (Missouri

Academy of Science, April 1938), and it will only be necessary to say here that the lands conveyed by the Morrill Act were mostly situated in the southern part of the state, and the people of that region were not satisfied to have the income from them wholly controlled by the authorities at Columbia, where the State University had been established. The Curators of the latter reluctantly gave their consent to the establishment of a School of Mines at Rolla, which was chosen because Phelps County made the highest bid ($130,545) of the rival claimants. It was formally opened Nov. 23, 1871, in half a building that had been constructed for a public school. There was considerable difficulty over the degree of control to be exerted over the Rolla institution by the authorities at Columbia, which finally ended in the president at Columbia being recognized as the president of Rolla, actual administrative control there being exercised by a director who, at first at least, was also a professor. C. P. Williams, professor of chemistry and metallurgy, was the first director. The report for the year ended June 21, 1873, shows a three-year mining and metallurgical curriculum, with no students in the third year, seven in the second, 10 first-year men and all the rest either preparatory or special. One man was graduated in mining in 1874 and two in civil engineering the same year. Like most of the early western institutions, there was much difficulty over the inability of local schools to prepare students to enter the first year of the curriculum.

Of the bid by Phelps County, $75,000 was to have been in cash, but only a small fraction of it was ever forthcoming, some 8000 acres of land being given instead, whose value failed to meet the promised sum by some $50,000. This added to the difficulty with the Curators of the University over the scope of the institution at Rolla. In 1885 the legislature authorized an academic course at the School of Mines, and the catalogue of 1889–90 lists eight curricula—mining, civil engineering, mechanical engineering, chemistry, mathematics and physics, academic and preparatory. The first five of these were three-year curricula leading to the B.S. degree; apparently engineering degrees had been conferred before that time. There was no professor of geology or of physics prior to 1891. D. C. Jackling took his B.S. degree in 1892, having also served as assistant in mining and metallurgy that academic year. The first woman graduate was in 1891. Walter B. Richards succeeded E. G. Harris as director on July 1, 1893. An alternative two-year curriculum in mining was offered at that time.

I have not been able to find a professor of mining listed in the early catalogues and the mining curriculum in 1892–93 was almost identical with that for civil engineering, except that one hour of mining instruction was substituted for C.E. field work in the third year and some metallurgical instruction was substituted for C.E. work in the fourth year. The curricula had been lengthened to four years and reduced in number to five. For a time thereafter, engineering degrees were again given.

In 1893–94, H. K. Landis (B.S., E.M. Lehigh) was appointed professor of mining, apparently the first one to hold that position. The total number of students in all curricula in 1895–96 was 72. Courtenay DeKalb was professor of mining and metallurgy in 1896–97. The next year his work was taken over by George E. Ladd, who had been appointed director the preceding year. After 1899 Ladd appears as professor of geology and mining, as well as director. F. W. Draper (B.S. M.I.T., 1895) was professor of metallurgy 1899–1900, and also taught ore dressing. H. O. Schulze (1899, Rolla) succeeded him the next year. In 1907 L. E. Young (B.S. Penn State, 1900; E.M. Iowa State, 1904) was brought from Colorado School of Mines, where he had been professor of mining since 1903, to become director. He remained there till 1913. Durward Copeland (B.S. M.I.T., 1903) was professor of metallurgy in 1909–10, and H. T. Mann (B.S. Rolla, 1908) was instructor. C. R. Forbes (E.M., M.C.M., 1903) was assistant professor of mining. C. Y. Clayton was instructor in ore dressing and metallurgy in 1913–14. A. L. McRae, professor of physics, was elected director in June 1915. Continuing difficulties with the Curators of the University were finally settled by court action about that time.

In 1920 C. H. Fulton was brought from Case School of Applied Science, where he had been professor of metallurgy since leaving the presidency of South Dakota School of Mines in 1911, as director and remained in that office until 1937. C. R. Forbes is still professor of mining, and C. Y. Clayton professor of metallurgy and ore dressing and director of the State Mining Experiment Station, which was established in 1909. William R. Chedsey became director in 1937 and was succeeded by Curtis L. Wilson in 1941.

As a result of this long period of continuous but hampered growth, the institution now offers four-year curricula leading to the B.S. degree in mining, metallurgical, civil, mechanical, electrical, chemical, and ceramic engineering. Petroleum engineering and mining geology are options under the mining curriculum and a general science curriculum, with the third and fourth years almost wholly elective, offers opportunity to major in chemistry, physics, geology, and biology. Engineering degrees in these fields are granted for three years satisfactory professional work in the field of the B.S. degree and the submission of an acceptable thesis. Master's degrees are given for graduate work on the usual basis. Candidates for doctor's degrees must register in the Graduate School of the University. It will be seen from the foregoing that the School of Mines at Rolla, though known by that name, has from its beginning functioned as a School of Technology, even offering academic work during part of its history. Since 1901 the State Geologist has maintained his office on the campus at Rolla.

Iowa

Iowa was one of the earliest of western states to establish a State university, and its first General Assembly as a State provided for one at Iowa City. In 1858 provision was made for a State agricultural college and a site was purchased at Ames. After the land-grant money became available this began to flourish. Though the main interest in Iowa was always agricultural, there seems to have been a sincere purpose to comply with the terms of the Federal grant-in-aid, so that as early as 1871 we find curricula in civil, mechanical, and mining engineering announced. The latter was identical with the mechanical engineering course, except that quantitative analysis, metallurgy, and mine surveying were substituted for theory of machines in the fourth year. The 1871 report lists all the classes taught, and none of these subjects are among them. The 1880 report describes the institution as organized into 12 schools, but mining is no longer among them. Just when it was revived I have not been able to establish, but in the 1896–97 report J. R. Lincoln, professor of mining engineering, says that he will need more room for classes next year; the curriculum is not given. The 1898–99 announcement lists S. W. Beyer as professor of mining; he was also professor of geology. Ira A. Williams is listed as instructor in geology and mining for 1899–1900. A definite curriculum is listed, which gradually becomes more distinct from the mechanical one until about 1900 they have only two years in common. L. E. Young became Beyer's assistant, was soon made assistant professor, but left and was succeeded by E. E. Bugbee in 1904, who was in turn succeeded by L. C. Hodson. During most of this period a two-year curriculum in mining was also offered, in response to the feeble demand for the longer one. After 1909 the two-year curriculum was dropped, and four-year and five-year curricula were both offered, the same degree, B.S. in mining engineering, being given for both. The reason given for the longer curriculum was the need for more general science and cultural studies, but it was dropped after 1918–19. At the same time mining was separated from geology. Professor Beyer concentrated on the latter and the former was assigned to S. L. Galpin, associate professor of geology, and A. K. Friedrich (B.S. Case, 1904), associate professor of mining. It soon became the whole care of Friedrich, and in 1928 the department of chemical and mining engineering became the sole responsibility of the Division of Engineering and of Industrial Science, and is still so maintained. Friedrich left in 1931 and was succeeded by F. C. Vilbrant, whose interests were in chemical rather than mining engineering. After he left the mining and metallurgical instruction was given by Kenneth A. Phillips, though still under the jurisdiction of the department of chemical and mining engineering.

Ohio

The land-grant institution in Ohio, which eventually became Ohio State University, was established as the Ohio Agricultural and Mechanical College in 1870. Its Board of Trustees, in January 1871, fixed its location at Columbus and decided that it should not only cover agriculture and the mechanic arts "but whatever practical instruction will make the labor of every individual class more successful and elevating." Among the 10 fields specified under this resolution was "geology, mining, and metallurgy." Edward Orton, then president of Antioch College, was selected to fill this chair and also was elected president of the College, which was formally opened on Jan. 8, 1874. In 1877 the legislature passed a bill establishing a "School of Mines and Mine Engineering" at the College, appropriating $4500 for equipment, and a professorship of Mines, Mine Engineering, and Metallurgy was created. Henry Newton, who had graduated from the Columbia School of Mines in 1869, had served as Newberry's assistant in geology and mineralogy there, and also in his work on the Ohio Survey, was appointed to it. In 1876 he had been appointed assistant on W. P. Jenney's survey of the Black Hills and he received his Ph.D. from Columbia just before the appointment at Ohio State, but while working in the Black Hills that summer he died of a fever without having begun work at Columbus. John A. Church, who had graduated as a mining engineer at Columbia in 1867, had studied in Europe, and had been assistant editor of the *Engineering and Mining Journal*, was appointed to the vacancy. He received a Ph.D. degree from Columbia in 1879 but left Ohio in the same year to engage in commercial work. Nathaniel W. Lord, who had taken his E.M. degree at Columbia in 1876, worked for a year in Central America, and was appointed State Analyst at Columbus in 1878, succeeded Church and remained in charge of the School until his death in 1911. Meanwhile, in 1878, the name of the institution had been changed to Ohio State University. Orton resigned the presidency in 1881, and became State Geologist as well as professor of geology in 1882.

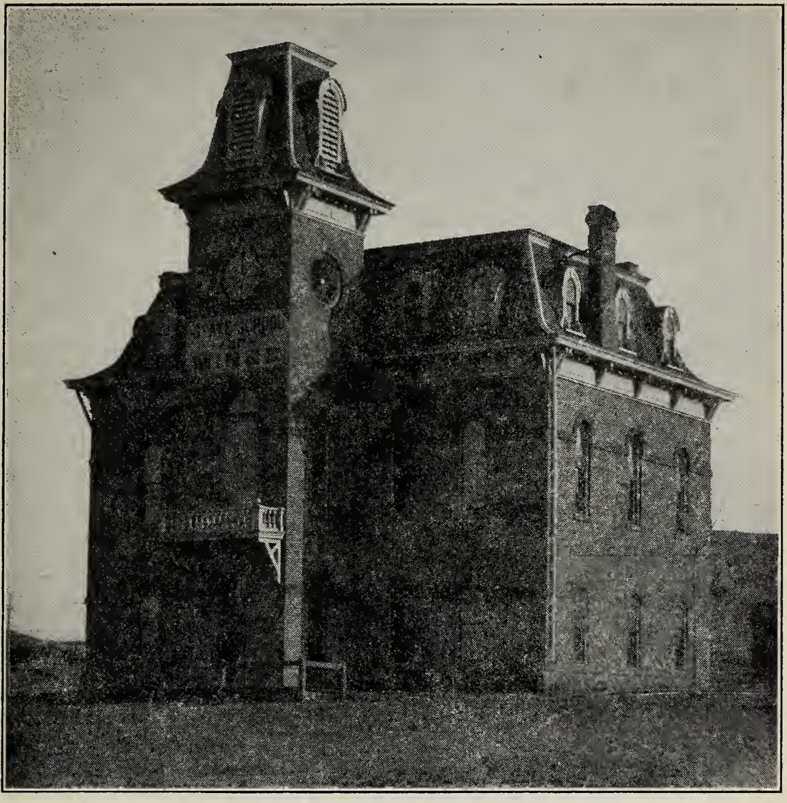
The first degrees in mining and metallurgy seem to have been given in 1880; two that year, one in each of the two succeeding years, then two each year until 1886, when four were granted. There were two in 1887, four in 1888, two in 1889, but apparently none in either 1890 or 1891. Lord had been appointed State Chemist for the Geological Survey in 1883, and while he published two or three papers on metallurgy his main interest was in analytical work and fuel testing. In 1894 F. A. Ray, who had graduated there as a mining engineer in 1887, was brought to the school as assistant professor of mining engineering, and became full professor in 1900.

To sum up, although so well established, and with such capable men on its staff, the School of Mines in Ohio State University graduated fewer than 40 men in mining and metallurgy in the first 20 years of its existence. Whether this was because the coal-mining industry of Ohio offered little opportunity for technical men, because there were so many other opportunities in the rapidly developing state, or because Orton and Lord, though men of the first rank, were chiefly interested in other things than mining and metallurgy, and deflected student interest, it is difficult to say.

South Dakota

In South Dakota the movement to create a publicly supported School of Mines originated while it was still a territory. The territorial legislature, February 1883, passed a bill creating a School of Mines at Rapid City, but the Governor vetoed it. In March 1885, the bill was repassed, carrying an appropriation of $10,000 to erect a building, $5000 for teachers and assistants, and $500 for fuel, lights, apparatus, and furniture for a two-year period. Three sites for the building were offered, and at the one accepted various donors gave 10 acres. The building was completed early in 1886. W. P. Blake meanwhile had been offered the presidency of the institution, but declined, probably because the salary offered was only $2500. He gave the School 41 books as a nucleus for its library and G. E. Bailey loaned it a collection of 5000 mineral specimens, which eventually became a gift.

After Charles L. Constant (E.M. Columbia School of Mines, 1877) had also declined, Franklin R. Carpenter[27] was elected dean of the faculty, and the School was officially opened on Feb. 17, 1887, with 20 students. The story of its early struggles against handicaps and the political difficulties that beset most State institutions has been told in detail by C. C. O'Harra,[42] who was its president from 1911 to 1935, and only a few points can be touched on here. One is the high quality of its early staff and that from the first (in contrast to the early staff at the Colorado School of Mines) they were all American born and trained, with the notable exception of H. O. Hofman, who, after teaching metallurgy there from 1887 to 1889, went to Massachusetts Institute of Technology to remain the rest of his life. Carpenter resigned in the same year, in protest against the appointment of Hofman's successor. He was followed in quick succession by George F. Duck, W. P. Headen, W. P. Jenney (E.M. Columbia, 1874) and V. T. McGillicuddy. The courses offered were mining engineering, civil engineering, and general science. There was a ten-year period in which there were no graduates and the school was for most of the time little more than a State-supported testing laboratory. Apparently, one of the major difficulties of the school was that it had such a small reservoir of prospective stu-



South Dakota School of Mines about 1890.

dents to draw upon, though political difficulties were also important. When South Dakota was admitted as a State in 1889, the Federal Government gave the School 40,000 acres of land.

Robert L. Slagle, who had graduated at Lafayette and taken a Ph.D. at Johns Hopkins, was appointed professor of chemistry in 1897 and was made president in 1899. A fresh period of growth started under his presidency and was continued under that of Charles H. Fulton (E.M. Columbia, 1897), who succeeded Slagle in 1905 and remained until 1911, when he became professor of metallurgy at Case School of Applied Science. C. C. O'Harra, a Johns Hopkins Ph.D. who had been professor of geology since 1898, then became president and for 24 years directed its continuous growth. J. P. Connelly, professor of mineralogy and petrography since 1919, succeeded to the presidency.

During the early part of this period elementary courses were gradually weeded out, as the schools of the region became better qualified to prepare students for entrance, and a full course leading to the degree of metallurgical engineer was first offered in 1906. The School now offers curricula leading to a B.S. degree in chemical engineering, civil engineering, electrical engineering, general engineering, geology, metallurgical engineering and mining engineering. It is thus a school of technology, admitting a few women to the curricula of interest to them, with the mineral industry as its major field of interest. Of a total of 43 senior students listed in the 1937–38 catalogue, three were candidates for the B.S. degree in mining and six in metallurgy. Another point of interest, which may be mentioned in conclusion, is the large number of Columbia graduates who have been on its staff. In addition to those already mentioned may be added M. F. Coolbaugh, professor of chemistry from 1906 to 1914; C. C. Van Nuys, on the physics staff from 1908 to 1916; Victor Ziegler, mineralogy, 1911 to 1914; F. W. Traphagen, professor of metallurgy, 1917 to 1921; and F. C. Lincoln, who has been professor of mining since 1923.

MICHIGAN

The Michigan Mining School, established by the legislature in 1885 and opened Sept. 15, 1886, in the attic and basement of the fire-engine house at Houghton, was the second State-supported school of mines to be established in the United States as an individual institution, physically and academically separate from any other. Perhaps it might claim to be the first, for the original plan for the Colorado School of Mines intended it to be part of a larger institution and the South Dakota School of Mines was a year later in actual opening. The establishment of such a school at Houghton had been proposed in the Michigan Legislature as early as 1861. The act establishing the School provided for a Board of Control of six members, and an appropriation of $25,000 for the first year. Albert Williams, Jr., was appointed principal of the School and professor of geology and mining; John D. Hoffman, instructor in mathematics and drawing; and Robert L. Packard, instructor in chemistry. During the next two years the Michigan school expanded into space made available in the Odd Fellows building and the roller-skating rink; in 1889 it moved into the present Hubbell Hall. The curriculum, at first only two years and not well organized, was increased to three years in 1889 and to four years in 1893. Seven bachelor degrees were given in 1888, and after the next year both the B.S. and E.M. degrees were granted. M. E. Wadsworth, a graduate of Bowdoin who had taken postgraduate work at Harvard, became its president in 1887. He has described its early development in such detail[64] that it seems unnecessary to summarize it here. The systematic development and improvement of its curriculum and equipment seems to have been largely due to his influence, while J. Parke Channing (E.M. Columbia, 1883) and J. A. Hubbell deserve credit* for stimulating public support for the institution.

During Wadsworth's presidency Hubbell Hall, used as a science building, was constructed, in 1889, at a cost of $100,000, an ore-dressing plant was built in 1890 and in 1892 a metallurgical and assay laboratory was added. The name of the school was changed to Michigan College of Mines in 1897. At the same time an elective system was adopted, which permitted students, by working 45 weeks per year, to complete the four-year curriculum in three years; since the adoption of the four-year curriculum in 1893 had cut the number of freshmen entering from over 40 to less than 20. F. W. McNair (B.S. Wisconsin, 1891), who had been professor of mathematics and physics at the school since 1893, succeeded Wadsworth as president in 1899 and served in that office until his death in 1924. During his presidency the physical plant was steadily increased; mining, metallurgy, chemistry, and administration buildings, and a powerhouse and a clubhouse being built. He maintained high educational standards, and the enrollment grew, reaching 336 in 1922. Many students came to the school from other states and foreign lands, and its graduates were widely distributed throughout the mineral industries. At first no tuition fees or laboratory fees were imposed, even on students from other states and foreign lands. In 1897 the legislature required the Board of Control to impose a $10 matriculation fee for residents and a $25 fee for nonresidents of the state. The tuition for nonresidents is now $50 per year.

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* Hubbell gave the land for the original campus.

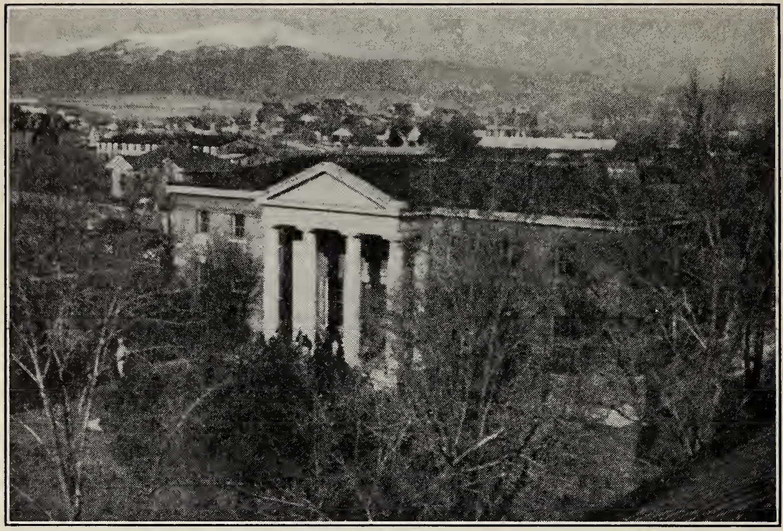
Hubbell Hall, Michigan College of Mines, 1889.

The legislature provided two new buildings in 1902, one for civil and mining engineering departments, and one for chemistry. A metallurgical building constructed in 1903 was destroyed by fire in 1923 and replaced by a much better building in 1925. Friends, staff, and students provided the funds to construct a clubhouse and gymnasium in 1906, a power plant was constructed in 1908, and a fireproof library, museum, and administration building was added in 1909.

Nevertheless, by the early 1920's it became clear that the copper-mining industry of Michigan could never be expected to reverse its steady decline through exhaustion of the ore bodies, and the iron-ore production of Michigan was also becoming a smaller fraction of the total output of the Lake Superior district. W. O. Hotchkiss, who had long been State Geologist of Wisconsin, became president of the College in 1925. After careful study of the situation the legislature was prevailed upon to again change the name to Michigan College of Mining and Technology, and to amend its charter to cover general technology. The degree granted for a four-year curriculum was changed to the B.S. in 1928 and curricula leading to that degree in chemical, civil, electrical, mechanical, and general engineering as well as in geology, chemistry, and general science were steadily developed. Another engineering building was constructed, and research in mineral technology was extensively promoted. Dr. Hotchkiss left in 1935 to become president of Rensselaer Polytechnic Institute, and was succeeded by Grover C. Dillman. Enrollment has grown rapidly from 150 in 1925–26, reaching 700 in 1936–37 and 950 in 1939–40. A residence hall was constructed in 1939. The support of the institution is mainly from biennial appropriations by the legislature. It has therefore become a general State school of technology, but remains under a Board of Control, separate from the University at Ann Arbor.

NEVADA

The University of Nevada was established at Elko in 1873, but never had over 35 students until it was moved to Reno in 1885. The 1886 Regents report mentions three curricula, one of them mining and metallurgy, and also speaks of a School of Mines. R. D. Jackson (Ph.B Univ. Calif., 1882) was professor of mining from 1887–88 to 1900–1901, when the university was reorganized into six colleges, with the School of Mines as one of the three schools of the College of Applied Science. The number of students was small and the first degree was given in 1892. George J. Young (B.S. Univ. Calif., 1899) became professor of mining and metallurgy in 1901 and was made head of the School in 1908, and Jay A. Carpenter (B.S. Nevada, 1907) became assistant professor of metallurgy the same year. In 1908 Mrs. John H. Mackay, as a memorial to her husband, gave the school a well-equipped building for mining and metallurgy, also an endowment fund for the salaries of the professors and the school was named the Mackay School of Mines. When Young went to the University of Minnesota in 1913 he was succeeded by F. C. Lincoln (S.B. M.I.T., 1900; Ph.D. Columbia, 1911), who had taught at New Mexico School of Mines, the University of Illinois, and Montana School of Mines. The latter was director until 1923, when he became professor of mining at South Dakota School of Mines. W. S. Palmer (B.Sc. Nev., 1905; E.M. Columbia, 1907) became instructor in metallurgy in 1910 and professor in 1917.



Mackay School of Mines, University of Nevada.

In 1924 John A. Fulton (E.M. Columbia, 1900) became director of the School and the same year Clarence W. Mackay pledged $18,000 annually for five years in addition to $100,000 for rebuilding the physical plant of the School. Frank S. Hunt gave the School 20,000 shares of Mountain City Copper Co. stock in 1924, the income to be used to pay the expenses of the students on summer field work in geology, and on trips to visit mining properties during term time. The average number of graduates between 1892 and 1899 was a little over five per year and is now about fifteen. The School now offers a four-year curriculum leading to the B.S. degree in mining engineering. When Fulton died in 1939, Professor Carpenter, who had been acting director for some time, succeeded him.

Alabama

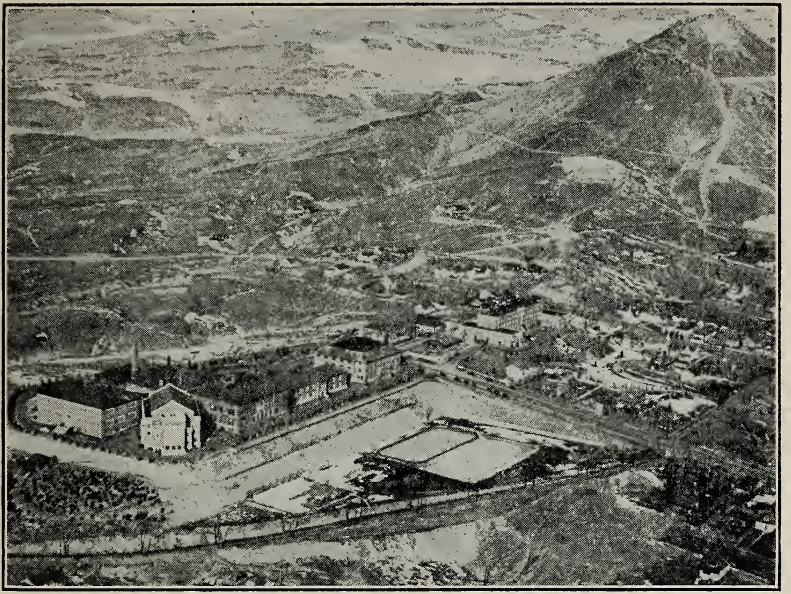
The University of Alabama antedates the other land-grant colleges because the State Assembly in 1819 passed a law which included a plan for the support of a State university through the sale or lease of lands given by the Federal Government. It began work in 1831 and, through appointing a professor of mathematics, natural philosophy, and civil engineering in 1837, may claim to be a close successor to Rensselaer Polytechnic in offering instruction in the engineering field. F. A. P. Barnard, afterward president of Columbia, was its professor of chemistry and mineralogy from 1837 to 1849. He was succeeded by Michael Tuomey, who was also appointed State Geologist. During the Civil War the University functioned chiefly as a military academy and it was practically destroyed when Federal troops invaded Alabama in 1865.

Opening again in 1869 with a new building, it gave the civil engineering degree for the first time in 1871. In 1887 a School of Mining and Metallurgy was established by its Trustees and the degree of bachelor of mining engineering was conferred on four men in 1888. There were no mining graduates for the next two years. After 1890 the degree was changed to E.M. for a four-year curriculum that was the same as the civil engineering one for the first three years. There were not many graduates from either before 1900. During this period mining instruction was under the direction of Eugene A. Smith.

In 1919 the legislature directed that all mining instruction should be centralized at the University, and designated the department of mining there as the School of Mines of the State of Alabama, thus effectually ending the competition in mining instruction with Alabama Polytechnic Institute at Auburn, another State-supported institution. A cooperative agreement was negotiated with the U. S. Bureau of Mines, which established an experiment station on the campus in 1921. H. D. Pallister, who was in charge in this period, secured the establishment of graduate fellowships, and the cooperative work was so successful that a new experiment station was built in 1935. J. R. Cudworth and L. I. Cothern were in charge from 1927 to 1939, when Cothern left to go to Virginia Polytechnic Institute.

Montana

Mineral industry education began in Montana at the College of Montana, at Deer Lodge, in 1887. That institution had been incorporated in 1878 as a Presbyterian school and began work as the Montana Collegiate Institute in 1883 with D. J. McMillan as president. It offered classical, scientific, and normal school curricula, and a three-year course in music as well. In 1883–84, the enrollment was 47 but grew as courses in art, stenography, typewriting and bookkeeping were added, the catalogue for 1889–90 showing a student body of 150. Frank W. Traphagen, who had taken his Ph.B. in chemistry at Columbia School of Mines in 1882, his Ph.D. in 1883, and had since been teaching chemistry and physics at Staunton Military Academy, Virginia, was appointed professor of general, analytical, and applied chemistry and assaying at the School (which meanwhile had been renamed the College of Montana) in 1887 and at once set about establishing a School of Mines there. In 1888 Augustus M. Ryon, who had taken his E.M. at Columbia in 1886, was called there as professor of civil and mining engineering and metallurgy. In an article published in the Columbia *School of Mines Quarterly* for November 1889 Traphagen describes the extensive plans for such work, but adds that the school had as yet only been able to organize a four-year curriculum leading to the E.M. degree. The announcement for 1891–92 shows 16 students and three curricula in the School of Mines—in mining, civil engineering, and chemistry—and two men as having taken their E.M. in 1891. In 1892 Ryon left to become president and professor of engineering at the State College of Agriculture and Mechanic Arts, at Bozeman, and Traphagen followed him there the next year as professor of chemistry. E. H. McDonald succeeded Ryon, and W. G. King succeeded Traphagen at Deer Lodge. The College of Montana closed in 1899, presumably for lack of financial support. It is possible that after Traphagen went to Bozeman he also endeavored to establish mining instruction there, but there is no record of it. Ryon left Bozeman in 1895, and Traphagen went to the Colorado School of Mines in 1903 as professor of chemistry.



Campus of Montana School of Mines from the air, 1940.

The act of the Montana Legislature in February 1893 that established the Agricultural College at Bozeman had also provided for a State University at Missoula and a State School of Mines at Butte. The act of Congress admitting Montana to the Union in 1889 had conveyed 100,000 acres of public land specifically designated for a School of Mines, in addition to the other lands for general educational purposes. This was used as security for a bond issue of $120,000 and the erection of a building was begun in 1896. The State made an appropriation of $26,000 for equipment and maintenance in 1899. The first students entered Sept. 11, 1900, and 39 were enrolled the first year.

Alexander N. Winchell was professor of geology, mineralogy and mining, and W. G. King, professor of metallurgy. The first two presidents were professors of mathematics, and this was a period of slow growth. A mill building was constructed in 1908. In 1913 the four State institutions were combined into one system called "the University of Montana," under a chancellor. Charles H. Clapp, professor of geology and mineralogy, was made acting president in 1919 and president the next year. A State Bureau of Mines and Metallurgy was established by the legislature in 1919, with an annual fund of $10,000 for operation; this is a branch of the school. A bond issue in 1920 provided $450,000 for a building for chemistry and metallurgy, another for engineering, and a new gymnasium. In 1921 Clapp went to the State University at Missoula, as president, and was succeeded by another professor of mathematics.

In 1928 Francis A. Thomson, who had been dean of the School of Mines at the University of Idaho, was appointed president, and another period of growth began. A state referendum in 1930 voted a tax of three mills for the university system, instead of depending upon biennial appropriations by the legislature as theretofore.

When the school was first established it offered two four-year curricula leading to the E.M. and E.E. degrees, but an electrical engineering degree was never conferred and the curriculum was discarded in 1903. In 1918 a curriculum leading to the degree of metallurgical engineer was established, but for the class entering in 1922 these degrees were changed to the B.S. in mining and metallurgical engineering. A curriculum leading to the B.S. in geological engineering was established in 1926. The curricula are identical for the first 2½ years. In 1929 provision was made for conferring the M.S. degree for advanced work in these fields, and in 1932 the degrees of E.M., Met. E. and Geological Engineer were reestablished as graduate degrees; to be conferred on holders of the B.S. who have had five years successful professional experience and have submitted a satisfactory thesis.

In addition, there is a general one-year curriculum for students expecting to transfer to other institutions. A six weeks short course for prospectors has been offered occasionally in cooperation with the State Board for Vocational Education. There is a faculty of 22 members and the total student body in 1938–39 (including general and special students) was 492. In all, 497 degrees have been conferred to 1940.* A notable feature is the close relationship between the School and the mines in Butte. One feature of this relationship is that a limited number of upper classmen are permitted to work one shift a week in the mines on either Friday or Saturday night.

New Mexico

The New Mexico School of Mines was established by the territorial legislature in 1889, which simultaneously provided for a University and a College of Agriculture and Mechanic Arts. It decided to place the School of Mines at Socorro, to be near the silver mines of that region, the Magdelena mining district and the Billings smelter. For its support one-fifth of a mill of the territorial taxes was allocated. A $60,000 building was completed in 1892 and academic work began in 1893 with a faculty of two, Floyd Davis being president and professor of chemistry and metallurgy, and T. S. Delay assistant professor of the same subjects. No instruction was given in 1894 but work was resumed in 1895, with the addition of a preparatory department, while the same year Congress gave the School 50,000 acres of public land. W. H. Seaman was made director of the School and was succeeded by F. A. Jones in 1898.

In 1902 C. R. Keyes became director of the School and proceeded to enlarge its activities to cover civil engineering and liberal arts. A new building was provided in 1903 and a dormitory in 1905. Apparently this was too rapid a rate of advance, and when R. P. Noble became president in 1906 various retrenchments were effected and liberal arts were dropped, though civil engineering was retained. When New Mexico became a state, in 1911, the ⅕ mill tax was dropped and the legislature thereafter made annual appropriation. At the same time 150,000 acres of land were added to the original 50,000 granted to the School, and in later years the income from this attained considerable importance. The years 1915–16 were again a period of growth. Rising from the interruption of the World War, development was resumed. Between 1896 and 1922 only 40 men received degrees, or an average of less than 2 per year. E. H. Wells became president in 1921. Although in 1922 the civil engineering curriculum was dropped, to avoid duplication of the instruction given at the State University and the Agricultural College, the average number of degrees granted between 1923 and 1937 was 17½ per year. To the curricula of mining engineering, metallurgical engineering, geological engineering, and general science offered, that of petroleum engineering was added in 1936. The general curriculum was abandoned in 1940. The New Mexico Bureau of Mines and Mineral Resources was established by the legislature as a department of the School in 1927. Additional buildings for engineering, petroleum engineering, and assaying and a dormitory were erected in 1939. C. E. Needham is now president, also director of the State Bureau of Mines and Mineral Resources.

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* A footnote of interest is that President Thomson reports not only that 459 are still living but that 79 per cent of them are engaged in work in the mineral industries.

North Dakota

The University of North Dakota was established by the territorial legislature in 1883 and began work the next year. Though it was granted 40,000 acres of public land for a School of Mines, the latter was not actually established until 1891, as the fourth college of the University, the others being Arts, Letters and a Normal College. (Education, Law, Medicine and Commerce have since been added.) In 1895 a State Geological Survey was established; the professor of geology in the University being ex officio State Geologist. Following the publication of the first report of the Survey in 1901, increased interest was manifested in mineral production, and E. J. Babcock was appointed dean of the School of Mines. In 1906 it began to offer optional curricula in the geological and engineering aspects of mining. A mining experiment station was established by the legislature at the University, with a branch at Hebron, and a School of Mines building was erected in 1908, providing increased facilities for the experimental and testing work. Ceramics was taken up in 1910. In 1917 the School of Mines was merged with all the other engineering work in a College of Engineering, and a curriculum leading to the B.S. degree in ceramic engineering was established.

The Engineer of Mines degree is awarded to holders of the B.S. degree in mining engineering after six years of practical experience, of which three must have been in responsible charge of work.

UTAH

As soon as the pioneers in what is now Utah had harvested the wheat crop of 1848 they turned their thoughts to provision for education as well as the organization of a government. A provisional government of the State of Deseret (whose boundaries were to include what is now Arizona and Nevada, plus parts of New Mexico, Colorado, Wyoming and California) was set up, and one of its first official acts was to incorporate on Feb. 28, 1850, the University of Deseret at Salt Lake City. Opening on Nov. 11, 1850, in the home of John Park, it seems not to have thrived, and was reopened in 1867 as a business college. After John R. Park became its president, in 1869, it began to grow and classes in mechanical engineering were offered as early as 1869.

In 1888 Dr. Park recommended that a School of Mines be established there, and the territorial legislature appropriated $2000 for a scientific survey of the state. Joseph B. Swenson received the first B.S. in mining engineering in 1893. In 1894 the Federal Government gave it 60 acres of the Fort Douglas reservation. J. F. Kingsbury, who made a report as principal of the mining school in 1894–95, said it had been suspended for two years but had been "reopened with much greater completeness."

The act admitting Utah to statehood in 1896 set aside 100,000 acres of public land for the mining school and the present site of the University was provided. In 1901 the state legislature passed a bill officially establishing a School of Mines and Engineering, stipulating that courses in mining, metallurgy and all branches of engineering pertinent to the Utah mining industry were to be offered. J. F. Merrill was principal of the school in 1899–1900, and records an appropriation of $3000 for apparatus and supplies. More must have been forthcoming, since in 1903–4 a metallurgical laboratory including a small-scale experimental concentrating plant, grinding room, assay furnaces, etc., was provided. By 1905–6 the School of Mines and Engineering was fully organized, with curricula in civil, mechanical, electrical, and chemical engineering as well as mining; in 1907–8 its total attendance was 190.

In 1913 the legislature provided for a separate department of mining and metallurgical research in the Utah Experiment Station. This provides for graduate work leading to the M.S. degree. Until 1931 a single curriculum in both mining and metallurgy prevailed and during the six years 1927–32, inclusive, the average number of graduates from it was 5.5 per year. Separate curricula in mining engineering and metallurgical engineering have since been established, with the ratio of graduates about two of mining to one in metallurgy, and an average of about seven graduates yearly.

ARIZONA

In Arizona the territorial legislature passed an act establishing a territorial university in Tucson in 1885, and authorized its Board of Regents to issue $25,000 in 7 per cent bonds to erect a building. The local people in Tucson tried to defeat the bill, as they had hoped to be awarded the capitol, the penitentiary, or the insane asylum. The town was expected to provide the land on which to erect the building, but nothing was done about it, and it was not until a group of professional gamblers purchased most of the present site and gave it to the state that construction work was started in 1887. The money originally provided for it was not sufficient to complete the building, and it remained unfinished until 1890, when $20,000 additional was obtained under the provisions of the Hatch Act, of which one-quarter was available for construction. To obtain this money it was necessary to organize a School of Agriculture, and the young lawyer who had secured the passage of the act creating the university was appointed professor of agriculture and director of the agricultural experiment station. Theodore B. Comstock was president of the University from 1893 to 1895, serving also as director of the School of Mines and professor of mining and metallurgy.

Academic work began in 1891, but as there were then no high schools in Arizona, only 9 of the 31 students who reported the first year were prepared to begin work of collegiate grade. The preparatory department was long the larger fraction of the student body at Tucson, and it was not definitely abolished until

1915. In that year the faculty numbered nine, and there were 60 collegiate students, about half of them in mining. William P. Blake had succeeded Comstock as director of the School of Mines in 1895, and served in that capacity and also as professor of geology until 1905, when C. F. Tolman became professor of geology and mining. William A. Tarr was instructor in geology from 1908 to 1910. Robert R. Goodrich was professor of metallurgy from 1907 to 1914 and Cyrus F. Tolman, now professor of economic geology at Stanford, was professor of geology and mining engineering from 1905 to 1912. C. H. Clapp succeeded Tolman as professor of geology in 1913 and remained until 1916.

Prior to 1915 only the B.S. degree was given by the University, without designation as to subject. The first to receive it for work in mining was R. L. Morton, in 1899, and 60 such degrees had been awarded by 1915. Many of these early graduates attained positions of considerable distinction. In 1915 G. M. Butler was made dean of the College of Mines and Engineering, and the B.S. degree in mining and metallurgy was thereafter awarded for the completion of its curriculum. New buildings and equipment were shortly thereafter provided, the entrance requirements and academic standards were raised and such men as F. L. Ransome, Charles Schuchert, E. P. Mathewson, W. M. Davis, B. S. Butler, T. G. Chapman and M. N. Short were added to the faculty. Since 1915, in all 176 B.S. degrees, 47 M.S. degrees and 20 Engineer degrees have been awarded in mining and metallurgy, and 24 M.S. degrees and 5 Ph.D. degrees in geology; the first of the latter in 1931. Of 208 living graduates in mining, 150 are still engaged in the work of their profession. In 1940 engineering and mining and metallurgy were separated, G. M. Butler remaining as dean of Engineering, and Thomas G. Chapman, who had been professor of metallurgy since 1916, was made dean of Mining and Metallurgy. The James Douglas memorial building given by the Phelps-Dodge Corporation (see frontispiece) was dedicated May 27, 1940.

TENNESSEE

The University of Tennessee, which had taken that name in 1879 after a long development out of Blount College, established in 1794, and which had received the Federal land grant in 1869, announced a four-year "mechanical course" in 1872–73, which was what we would now call general engineering; but in 1878–79 there were only two such students in the senior class, and nearly as many students in the preparatory department as in collegiate work. After 1883–84 it called itself the State Agricultural and Mechanical College as well as University, announcing a four-year engineering curriculum in the mechanical college. In 1887–88 it announced a course in mining engineering, and the degree of mining engineer to be awarded for two years' work beyond the bachelor's degree. At the time the school was so weak in its upper grades that it awarded only three bachelor degrees in June 1888. The arrangement was soon changed to a four-year curriculum leading to the B.S. in mining engineering; metallurgy was an option in the School of Chemistry. The announcements after 1892–93 do not show any mining instruction in the mining curriculum; apparently no one with the title of professor or instructor in mining was ever appointed. The curriculum itself disappears with the 1896–97 announcement.

In 1907 Royal P. Jarvis, who had been doing graduate work at Columbia since leaving Washington State in 1906, was made professor of mining and metallurgy, and curricula leading to the B.S. degree in both mining and metallurgy were established. After Jarvis left in 1915 the separate curricula in mining and metallurgy were dropped and a geology and mining curriculum was offered, with no indication who taught the few mining courses listed. That curriculum was also dropped after 1917–18. The reasons why the mining curriculum did not succeed there are probably the same as for Vanderbilt University (see p. 114), the most important one probably being that there was not sufficient interest in mining as a career among the student body tributary to the school.

Chapter 8

GROWTH IN THE EAST

IN this survey of the progressive development of education for the mineral industries throughout the United States, the review of the history of each school has usually been completed wherever it is first mentioned, but the history of the schools in the cities of the eastern seaboard was not carried beyond 1870. It is necessary now to cover what happened during the period of approximately the last quarter of the nineteenth century in several of the schools in the east.

Philadelphia

Of Philadelphia, it has been related in chapter 4 that the Polytechnic College of Pennsylvania began offering a curriculum leading to the B.S. in mining in 1853; that the school did not prosper, and finally closed about 1890. The establishment of a Department of Mining, Arts, and Manufactures at the University of Pennsylvania in 1855–56 was also mentioned, but its history was not carried beyond 1860. In 1859 J. Peter Lesley was appointed professor of mining in the University of Pennsylvania. The son of a cabinetmaker, born in Philadelphia Sept. 17, 1819, he had taken his A.B. degree at the University of Pennsylvania in 1838 and then secured a position on the Geological Survey of Pennsylvania under H. D. Rogers. When the Survey was discontinued, in 1841, he went to Princeton to study theology, was ordained a Presbyterian minister and followed that career until 1852, when the Pennsylvania Geological Survey was again started and he rejoined its staff. He published "A Manual of Coal and its Topography" in 1856, and studied at the École des Mines, Paris, in 1856–57. He published an 800-page "Iron Manufactures Guide" the year that he was appointed to the staff at the University of Pennsylvania.

In 1863–64 a College of Agriculture, Mines, Arts and the Mechanic Arts was established, but it was not a separate school and Lesley, Frazer, Rogers and Trego were not listed as members of the Arts College faculty. It struggled along, with five or six students yearly, most of them interested in civil and dynamical engineering, until 1872–73, when it disappeared, and a Department of Science with Lesley as dean was announced, having four curricula, one of which was geology and mining. Soon there were 97 students in the department and 12 officers of instruction, most of them not listed as faculty members.

The Department of Science was renamed the Towne Scientific School in 1875 because of the bequest of John Henry Towne. Though Lesley was listed as dean, it did not have a faculty of its own until 1912. Two new curricula were announced. Organic chemistry, the coal and iron mines of the United States, copper, lead, etc., in the United States and elsewhere, and mapping and surveying are the courses listed for the curriculum in geologic mining, which may be taken to indicate that it was yet little more than a plan. In 1879–80 it was a little more fully developed, and the 1889–90 catalogue states that the E.M. degree will be given for a year's work beyond the B.S. of the Towne School. (Later this was changed so that the Engineer degree could be taken by B.S. men who had had three years experience and presented a thesis.) The only courses specifically listed in the catalogues were four in metallurgy by G. A. Koenig (who was also professor in mineralogy), and three on mining by Amos P. Brown, who is recalled by his students as an able teacher and a man of wide experience. The 1895–96 announcement is the last in which mining is mentioned. Over the period 1851–1896 the University of Pennsylvania had given 33 B.S. degrees in mining, and 7 Mining Engineer degrees.

No subsequent attempt was ever made to establish education for the mineral industry in Philadelphia, and it is difficult to understand why the efforts made were without success. Certainly it was not from lack of competence on the part of the teaching staff of the University of Pennsylvania, though Lesley surely had too many irons in the fire. He was sent to Europe by the Pennsylvania Railroad to study rail manufacture and the Bessemer process, and he worked so hard as a consultant to petroleum companies that he had a breakdown in 1866. After recuperating in Europe he became, in 1869, editor of the weekly "U. S. Railroad and Mining Register," and from 1873 to 1887 he was director of the Pennsylvania Geological Survey. Apparently he had no active connection with the University after 1882, although his name appeared in the faculty list until 1902–3. He suffered another breakdown in 1894 and died in 1904.

Faulty academic organization, which delayed for so many years the recognition of engineering as a field of instruction that should have a faculty of its own and definite curricula leading to recognized degrees, was certainly a great handicap at the University of Pennsylvania. The simultaneous existence of two institutions in Philadelphia, both offering instruction in the mineral industry field on an unsatisfactory basis, probably hampered both of them. Before these drawbacks were remedied instruction at Lafayette, Lehigh, the University of Pittsburgh, and Penn State, all of which are nearer to mines and metallurgical establishments than Philadelphia, was so firmly established that it was too late to build up instruction in these fields at the University of Pennsylvania. The copper, zinc, and nickel deposits of eastern Pennsylvania, though at one time a source of great interest, never amounted to much and this may have reacted to decrease student interest. At any rate, although there were three institutions (including Yale) offering instruction in mining or metallurgy before the School of Mines at Columbia was founded, none of them was successful.

Boston

At Boston Raphael Pumpelly had been appointed professor of mining at Harvard in 1865 and Massachusetts Institute of Technology offered a curriculum in mining and metallurgy when it opened in the same year. The developments that resulted in the dropping of mining instruction at Harvard in 1874 have already been chronicled, in chapter 6; those that followed upon its revival in 1894 must be postponed to the next chapter. What happened at Massachusetts Institute of Technology between 1865 and 1873 has also been related in chapter 6, and the events of the next 20 years must now be set down.

Robert H. Richards, a member of the first class (1868) that graduated at M.I.T., had held the title of professor of mineralogy and assaying, in charge of mining and metallurgical laboratories, during 1871–72. When Alfred D. Rockwell, the professor of mining, left in 1873, Richards, not yet 29 years old, was made professor of mining and head of the department of mining and metallurgy. The curriculum in mining and metallurgy was known as Course III and up to 1891 it had granted a total of 116 S.B. degrees, or an average of 5 per year. Though the numbers were small they included many men who later attained great distinction. Henry M. Howe graduated from Course III in 1871; Charles H. Goodale in 1875; Henry D. Hibbard, Frederick W. Wood, and John E. Hardman in 1877; Baron Takuma Dan, 1878; Harry H. Campbell, 1879; Arthur Winslow and John H. Allen, 1881; T. W. Robinson and C. Snelling Robinson, 1884; David Baker, 1885; Walter R. Ingalls, 1886; Albert Sauveur and Jasper Whiting, 1889; Allen H. Rogers, 1890; W. Spencer Hutchinson, 1892; George Moore and Robert Mannesman, 1893; Archer E. Wheeler and Fred W. Draper, 1895; Bradley Stoughton and Charles E. Locke, 1896.

Metallurgy was at first taught by John M. Ordway, who was also professor of industrial chemistry, and later developed the biological department. Henry M. Howe gave the lectures in copper metallurgy from 1884 to 1897; in 1889 Heinrich O. Hofman was called from South Dakota School of Mines to become assistant professor of metallurgy and was made associate professor the next year. In 1898 he was made full professor and succeeded Richards as head of the department in 1914. Richard W. Lodge, '79, after previous service as assistant, became a member of the permanent staff in 1889 and taught assaying until 1907, when he was followed by E. E. Bugbee.

The six students who completed Course III at M.I.T. in 1868 were nearly one-half (6 out of 14) of the total graduates that year; the three who graduated in 1895 were only 2 per cent of that year's total graduates, indicating that the mineral industry instruction did not show the same rate of growth as the rest of the Institute. It persisted, however; the next year there were 10 graduates and in 1899 there were 21. Consideration of the period of growth that followed must be postponed to chapter 9, while we return to New York and relate what had happened in the third of the three great eastern cities, which had been since before the middle of the century the largest of them all.

New York

Columbia was the only institution in New York that ever attempted to offer mineral industry education, and its development there was not carried beyond 1868 in chapter 5. It may be recalled that Columbia School of Mines at that time began offering five curricula, covering civil engineering, geology, and chemistry as well as mining and metallurgy. The title of F. L. Vinton was changed from professor of mining to professor of civil and mining engineering. One student entered the civil engineering curriculum in 1869–70 and one more the next year. One student in geology had entered in each of the years 1866–67, 1867–68, and 1868–69, but none entered in 1869–70 and 1870–71, and not more than one before 1876–77. The growth of registrations in the chemistry curriculum was a little larger, but was also slow.

As a matter of fact, there was no great difference between the five curricula at this time. They were all modeled on the mining curriculum, with not much greater differences than we would now rate as an option. Even the chemistry curriculum was enough like the mining one so that an able student could complete all the requirements for both degrees with not more than one extra year's work. During the following years there was progressive differentiation and enrichment of the work given by the several departments. After 1870 the School of Mines began to give Ph.D. degrees for advanced work. According to the faculty minutes, one was awarded to W. G. Peck in 1870 for a mathematical dissertation, but the University records show this as having been awarded in 1877. Another was awarded to Elwyn Waller in 1875 for a chemical dissertation; four were given in 1876 and six in 1877. Many of the men who had taken the Engineer of Mines degree went on to graduate work in other fields. A. H. Chester took his E.M. in 1868 and received a Ph.D. in 1878 for a dissertation on the crystal forms of gold; meanwhile he had been professor of physics at Hamilton College. Carl Barus, a member of the class of 1877, did not complete the work for the E.M. but took a Ph.D. at Wurzburg in 1879 and later became professor of physics at Brown University. Nathaniel L. Britton took his E.M. in 1879, a Ph.D. in botany in 1881, and later became director of the New York Botanical Garden.

The point of this is that the men who went out from the School in its early days to successful careers in the mineral industry were not its only product; it was also functioning as a school of science to develop scientists. Apparently dissatisfaction arose among the alumni because the instruction given was not more narrowly professional, and Vinton became the focus of this dissatisfaction. A man of great personal charm and marked teaching ability, he had not had opportunity for industrial experience, and his teaching duties, which ranged from drawing to civil and mechanical engineering topics as well as mining, must have left him little opportunity for contact with industry. Whatever the precise cause, the chair of civil and mining engineering was abolished in the spring of 1877 and William P. Trowbridge, who had been professor of dynamic engineering at Yale since 1871, was brought in as professor of engineering; Henry S. Munroe, who had taken his E.M. in 1869 and Ph.D. in 1877, was made adjunct professor of surveying and practical mining. Frederick R. Hutton, E.M. '76, was made instructor in mechanical engineering. Thus three men were provided to cover the field that had previously been assigned to one.

After taking his E.M. in 1869 Munroe had been for a year an assistant, on the Ohio State Geological Survey, to Dr. Newberry, who was simultaneously State Geologist of Ohio and professor at Columbia. Next he was a chemist in the Department of Agriculture for a year before becoming assistant geologist and mining engineer on a geological survey of Hokkaido, Japan. After three years of that he became professor of geology and mining in the University at Tokyo, but remained there only one year. He was granted the Ph.D. at Columbia in February 1877 for "advanced studies in economic geology and analytical and applied chemistry."

Taking up his duties at Columbia with zeal and enthusiasm, he made a notable advance before beginning his first year's classroom work. The Trustees had appropriated $1000 to defray the expenses of a class in practical mining to be held during the summer of 1877. Eckley B. Coxe, who was keenly interested in education for the mining industry (see p. 251), made the anthracite mines at Drifton, Pa. available for conducting this summer school, and the work was carefully planned in advance. Since two detailed accounts of this first effective summer school of mining have been published,[40,61] it will suffice to say here that squads of two or three students were assigned to work with miners, going in just after the shift started and coming out just before. For the first few days they helped the miners but thereafter only observed and recorded their operations. By routing the squads around from place to place, they were given opportunity to make a careful study of drilling, blasting, loading, and tramming, hoisting, and all the accessory operations, including the surface shops. It is not clear whether during the first year the students were required to hand in their notebooks, so that a careful daily check on how well they were observing could be maintained, but it was done in later sessions.

After three weeks had thus been spent in the intensive study of the operations of one mine, a week or ten days was devoted to visits to near-by properties, now concentrating on the significant differences in techniques used and the reasons for them, thus presenting an opportunity for the students to grasp the concept of a typical mining operation. Anyone who has shown a mine to persons unfamiliar with mining operations knows how essential this sequence is. The operation is so large, and all its individual elements are so unfamiliar, that only after each element is understood can their relation be understood. The work was so well planned that it was conducted along the same lines, except in minor detail, for the next 30 years. Graduates reminiscing about their early experiences almost invariably say that they found this supervised summer work the most enlightening and helpful part of the curriculum. Thirteen students attended the first summer school, which was voluntary, but it was immediately incorporated into the curriculum as a requirement for the Engineer of Mines degree.

The published accounts of the first summer session do not make clear how much attention was given in it to underground surveying. The students had had field practice in surveying in Central Park, underground surveying was discussed in the classroom, and very soon practice in it was incorporated into the summer school, the squads taking turns at carrying a line underground by plumbing a shaft, and in surveying stopes. Professor Munroe taught plane surveying as well for a number of years, and in 1884 organized a summer school of surveying at Pelhamville, N. Y. to replace the unsatisfactory brief periods that could be devoted to it during the school year. After a preliminary lecture from 7:45 to 8:30 each morning, the rest of the day was given to a graded series of exercises, beginning with pacing and ending with a plane-table survey. After a couple of years this camp was moved to Litchfield, Conn., the field work being done on tracts of more or less waste land. In 1891 a 120-acre farm was leased. The next year this surveying work was taken over by the civil engineering department. In 1903 the University bought the farm and others adjoining, acquiring a total of 500 acres. Field work in geodetic surveying, given by the astronomy department for civil engineers, was started in another place at the same time but eventually was consolidated with the other at Litchfield.

The good results from the summer school of mining inspired F. R. Hutton, then instructor in mechanical engineering, to organize supervised summer instruction in machine-shop work in and around New York. I can find no published explanation why this was discontinued after a few year's experience with it, but one can imagine various practical difficulties that might have been the cause. There was not as yet a mechanical engineering curriculum in the School of Mines, and the mining and civil engineering students may not have been sufficiently interested in machine-shop work to be willing to use additional summer time on it. To trace the present extensive development of summer-session work in various fields of education back to Professor Munroe's pioneer school at Drifton, Pa., in the summer of 1877 seems entirely warranted. The conditions that led to the discontinuance of the school, in its original form, after about 30 years, will be discussed in a later chapter.

As early as 1877–78 Munroe instructed the fourth-year mining and metallurgy students for two hours a week in ore dressing (as well as in mining practice), and this was increased to three hours in 1879–80. The students had 14 to 15 classroom hours per week and spent the rest of the day in laboratory work. It would require too much space and be tiresome to trace the changes from year to year, but the curriculum was always a heavy one; much of the time there was no regularly scheduled lunch period. It also had a broad basis of natural science. Astronomy was dropped from the mining curriculum in 1879–80, but the mining students continued to get some instruction in botany and zoology, as a preface to geology, until after 1900. In passing, it may be noted that the present departments of botany and zoology in Columbia University grew out of the instruction in those subjects given by the geology department until 1891, and thus have their origin in the School of Mines.

The entrance requirements to the Columbia School of Mines were always higher than those of Columbia College. As early as 1868 the entrance examinations covered algebra, geometry, plane and spherical trigonometry, physics and general chemistry. At first French and German were taught in the School but were gradually crowded out by increased instruction in technical subjects, and were made prerequisites; two years each of both languages. High standards of admission and efficient, sound academic organization are probably the principal reasons why the Columbia school was so much more successful than the others described.

In 1881 F. Augustus Schermerhorn (E.M. 1868) prevailed on the Trustees of Columbia to establish a curriculum in architecture. William Robert Ware, who had established the curriculum in architecture at Massachusetts Institute of Technology in 1866, but was then in private practice, was made head of the new department, at a salary of $5000.* As Columbia was then organized, architecture would have had to become a department of either the College or the School of Mines, and the latter seemed the more suitable. It did not work out well. Apparently the first idea of the faculty was to have the architects take the same first year or two as the other students, specializing in the third and fourth years, but the architects could not see the value to them of basic instruction in chemistry, physics, botany, hygiene, etc., and in such fundamental subjects as they were interested they wished the instruction to be based on what an architect needed to know. Before long the architecture department was teaching its own students analytical geometry, descriptive geometry, calculus, and analytical mechanics, and the gap between the curricula steadily widened. After 1897 architecture was recognized as a separate school and after 1902 it had a separate faculty. But we must return to the School of Mines in the eighties, and postpone discussion of the eventual results of introducing an architecture curriculum into it.

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* Newberry's salary in 1866 was $3000, but was raised to $4000, with a "temporary" 25 per cent additional, in 1867, as was that of Egleston, Vinton, and Chandler. When Trowbridge was brought in, in 1877, his salary was $7500 and the others were given increases. There was no fixed scale, and apparently there was a few years' lag, as compared to the long cycle of declining wages and salaries which set in after 1873.

The number of E.M. degrees granted by Columbia in 1884 and 1885 (38 each year) was approximately 50 per cent more than in the immediately preceding years. The class of 1884 at M.I.T. was more than double the size of its predecessors, but as none of the other schools of the country showed any corresponding increase any general explanation of the facts is not apparent. Virtually every school in the country, however, showed a marked drop in the class of 1888 as compared to 1886–87, so there must have been a general cause for it, though its detection is again baffling. Apparently fewer mining and metallurgical degrees were granted in the whole United States in 1888 than had been given any year since 1875. There was some recovery in 1889 but 1890 was even smaller than 1888.

Between 1888 and 1891 various steps were being taken at Columbia School of Mines to establish instruction in electrical engineering. At first a graduate course, it was put on a regular four-year curriculum basis, leading to the E.E. degree, in 1891. Five of the earlier students received the degree that year and thereafter a considerable proportion of the freshman class were electrical students. The School of Mines was now offering seven different curricula leading to appropriate degrees.

Another event in 1891 was the creation of a separate Mining Department, with Munroe, as full professor, in charge.* In 1892 Robert Peele, E.M. 1883, was made adjunct professor of mining and the content of the courses given by the department was correspondingly strengthened. Between 1895 and 1900 the number of yearly graduates in mining was about double what it had been in 1890–95. In 1896 the name of the School was officially changed to Schools of Mines, Chemistry, Engineering, and Architecture, but it still remained under the control of a single faculty, with Chandler as dean.

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* As adjunct professor of mining he had been a member of the Engineering Department of which Trowbridge was the head.

Contrasting Data

We therefore see that in the period 1870–1895 mineral industry instruction in Philadelphia completely died out, never to be revived. In Boston it had disappeared at Harvard during most of the period, but was resumed in 1894, as will be related in the next chapter. At Massachusetts Institute of Technology it had pursued an even course, or perhaps a slight downward trend, as the average number of S.B. degrees given in mining and metallurgy in 1891–95 was 4, as compared with an average of 5 for the period 1868–1891. At Columbia School of Mines there were ups and downs, with peaks in 1868 (19), 1878–79 (23 each) and 1884–85 (38 each) and intervening depressions in 1873 (5), 1881 (15), and 1891 (5), the last being the smallest year (except 1873) since the opening of the School. Nine degrees in architecture were given by the School of Mines in 1891. During 1891–1901 there was a general upward trend which brought the number of yearly graduates in mining* back to the level it had exceeded in 1878–1887. After 1901 there was a rapid and steady growth that persisted until 1911 and the cause for this will be discussed in the next chapter.

It may be well to note that here, as well as in all other schools, there were many men who attended long enough to appear on class lists, and who often attained distinction in after life, but who did not take their degrees. There are 58 names in the class list of 1891, School of Mines, though only 32 degrees of all kinds were awarded that year, and only 5 E.M. degrees. Thus the apparent huge success of the Columbia School of Mines in the period 1864–1894 is somewhat inflated, since by the end of the period it was offering seven curricula, and the attendance on some of them was larger than it was in the mining curriculum. But even allowing for that, it still remains true that throughout the period the Columbia School of Mines was, on the average, granting about as many mining degrees yearly as all the other institutions of the country combined, although it had more rigorous entrance requirements and a more difficult curriculum than the others.

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* The degree of Metallurgical Engineer was first given in 1886 and 10 such degrees were awarded in 1887–1890, whereas no Ph.B. degrees in metallurgy had been awarded between 1876 and 1886.

One is immediately impelled to inquire why this was true. After long consideration of that question the author can make no other response except that he does not know, none of the explanations that have been suggested impressing him as really valid. It is true that in some places the "professor of mining" was merely an economic geologist, without engineering training or experience, that in others the curriculum was not well organized, the degree offered lacked attractiveness, it was difficult to attract properly prepared students, or there was something else that could be blamed, but the conditions in the different schools were so different, while the contrast between Columbia and the other schools is so distinct, that it seems unwise to attempt to draw any general conclusion. It is true that in 1890 New York had 2½ times the population of Philadelphia and 5 times that of Boston, but between 1890 and 1930 New York more than doubled in size, without any corresponding increase in interest in mineral industry education. Nor does the suggestion (which has been made) that it was the sons of doctors, lawyers, and business men in New York and Brooklyn who went to Columbia for education for life, found the curricula of the School of Mines the most attractive, and went on to make a personal success in the mineral industries, seem a sound explanation, since surely there was a similar clientele available in Philadelphia and Boston. The fact remains that prior to 1890 Columbia had given about half the mineral industry education degrees awarded in the United States, and had given some training to a much larger number of men who did not take their degrees, of whom William Boyce Thompson, ex-1893, will serve as a type. The causes for the different experiences at the different places are probably many and complex.

CHAPTER 9

THE END OF THE CENTURY

THE decades immediately before and after the end of the nineteenth century (1890–1910) were a period of increased activity in mineral industry education. One reason for this, undoubtedly, was the rapid increase in mineral production in the decade 1880–1890; pig iron and copper production tripled; coal, lead, and zinc output more than doubled. Most of the other mineral substances followed the same general trend. Aluminum production began in 1886; petroleum output, which in 1888 was less than it was in 1882, almost doubled in the next three years. Gold alone showed no appreciable change until its discovery at Cripple Creek in 1891, followed by the Klondike in 1896, brought to boiling a public interest in minerals that had been simmering for some years previously. The first cyanide plant in the United States was erected at Bodie in 1892, and the first chlorination plant at Cripple Creek* the next year. Silver-lead smelting had already greatly developed, and the metallurgy of copper was almost transformed. The hearth area and smelting capacity of copper reverberatory furnaces more than quadrupled between 1878 and 1894; matte converters were first erected at Butte in 1884. Copper production of the United States in 1899 was 20 times that of 1872. While it was the increased technology used in mineral production that really made the field attractive for educated young men, undoubtedly they did not realize that, and were impressed mainly by the quantitative increase in output.

Another factor was the increased general interest in engineering education; three times as many men took engineering degrees in the United States in 1890 as in 1880; 1892 showed almost a 56 per cent increase over 1890. Industry had come to recognize that technical training was worth while. The mineral industry lagged somewhat at first; the total number of mining degrees given in 1881–90 exceeded the preceding decade by only 50 per cent, and three less were given in 1890 than in 1880. But the late nineties and early 1900's were a period of rapid growth in enrollment in mineral industry curricula where they were already established, and of their initiation at many additional institutions.

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* One was built at the Phoenix mine, North Carolina, as early as 1879.

A third reason, to which a good deal of weight should probably be attached, was the discussion of mining engineering education that was initiated by a series of articles on the engineering schools of the United States published serially in *Engineering News*, beginning March 19, 1892 and extending to June 1893. Though not signed, everyone knew they were by A. M. Wellington (best known for his "Economic Theory of Railroad Location") who was then one of the editors of the magazine. Before the series was completed attention had been somewhat diverted from the main issues by disputes between the author and educators over the precise figures as to hours of attendance, course requirements, and especially as to summer vacations, which Wellington thought were a waste of time. But undoubtedly they were of great effect in preparing the ground for the conference on Engineering Education that was held in August 1893, in connection with the Chicago World's Fair, out of which grew the Society for the Promotion of Engineering Education.

Wellington's Articles

What concerns us is that in the twenty-fourth article of the series (Oct. 6, 1892, p. 328) Wellington said:

> One puzzling question, at least, seems to be answered clearly enough in the accompanying diagram, viz., why the mining courses are so rapidly falling into innocuous desuetude. The average mining course as shown on the diagram would seem to be a most ill-judged course, from which no possible student can gain any advantage, unless he proposes to become a kind of scientific prospector. What are the duties of the mining engineer? One would suppose from the average distribution of time that the college conception of him was as of a man who goes roaming about the earth for strange geological formations, hunting for new rocks to analyze, assay or blow-pipe, from which he may get a good "show" for a new mine. The imagined being does not exist, at least not in numbers sufficient to warrant schools for training him, as he is at a great disadvantage with the rustler for grubstakes when he does exist. On the contrary your typical mining engineer is a hum-drum sort of fellow who takes a mine as it exists and contents himself with managing and extending its machinery, plant, reducing works (if any), drifts and shafting, and accurately surveying and map-

ping it, with some occasional simple chemical work. Except for general information he has no more need of profound geological knowledge than his workmen; all he knows which he uses practically he acquires just as his workmen acquire it, by practical experience with and observation of the particular formations that he is working in at the place where he is working. All the chemistry he uses (when he uses any) are a few routine processes, soon learned, for dealing with his particular ore. His special reason for being is that there are engineering duties connected with mining work for which some special training is necessary. But the kind of training needed for this is precisely that which the civil and mechanical engineer gets, not at all what the chemist gets.

Therefore the mining engineer who graduates from the average course is at a disadvantage even on his own chosen ground. He is neither fish, flesh, nor red herring. He is not so good an engineer as those who graduate from the other engineering courses, because he has not been so thoroughly grounded in engineering. He is not so good a chemist as those who graduate from a chemical course for the same reason. Other things being equal the civil or mechanical graduate will beat him on his own ground, while he is not nearly so well qualified to compete with them on theirs.

This was the last straw, for in his August 11 article (p. 139) he had said:

As for mining engineering, what is there about the ordinary work of the ordinary mining engineer which requires a different training from that of a mechanical engineer? Chiefly a certain amount of metallurgical and prospecting or sampling work. But to become a specialist in this kind of work a man should be a chemist and metallurgist at once, and nothing else. After a mine has once been discovered, and its value approximately determined (the doing of which affords steady and profitable work to few or none), the chief work of the mining engineer is to open and operate the mine advantageously; and the knowledge and experience of a civil or mechanical engineer gives just the right preparation for this kind of work. Such is the result in practice, evidently, for mining engineering itself is a rapidly expanding department of professional work, while the number of graduates from mining schools has been steadily declining since it reached its climax (of 61 graduates only) in 1884.

This has been in substance the experience of all the schools alike, and not of one school only, nor is the decrease caused by the abandonment of mining courses at the several colleges, but simply by a decrease in the number of students taking such courses.

This is shown in detail in the accompanying Table XV, giving a substantially complete return of the graduates from all the mining schools of the United States.

The backbone of mining education in this country has always been the Columbia College School of Mines, which is now practically abandoning the special field which its name implies, and turning out large classes in the other branches of engineering instead. In fact, had we taken "the face of the returns" for Columbia, the few "miners" which appear for 1891 and 1892 would not have appeared as such at all. They were returned to us as mechanical engineers with

> the mining column blank, and perhaps, correctly*; but as so complete a change seemed improbable we have included the alleged mechanicals as mining graduates.
>
> As a rule Columbia has turned out each year from half to two-thirds of the total number of mining graduates since it set the fashion of having such a course in 1863–7. It started in with remarkably large classes, which fell off during the panic era of 1873, but sharply recovered up to 1878–85, after which date the turn and permanent decline seems to have begun.

He had followed this by saying (Sept. 22, p. 269):

> The mining courses we had not considered at all in this part of our investigations when the college had any other engineering course, as separate courses for mining engineers seem to be going out of date, and the mining course is apt to be cast in the same lines as the other courses, where there are any others.

These slights on mining curricula elicited a long rebuttal from Professor Munroe[39] pointing out errors in the chart from which Wellington's deductions of Oct. 6 were drawn, and also arguing that a mining engineer does not need to know as much as other engineers about the basic theory of engineering, because he is engaged in destruction, not construction. He next makes the point, from Columbia records, that 92 per cent of its graduates were then engaged in professional work, as compared to 75 per cent in 1883: "Including the geologists who are at work in the mining regions or who are teaching in mining schools, 60 per cent are doing the work for which they were trained in the school. In 1883 but 46 per cent were so engaged."

Omitting various parts of the argument as not now particularly germane, Professor Munroe also pointed out that but few civil and mechanical engineers at that time found employment in the mineral industry, but since he does not raise the question as to whether men classed as surveyors and assistant engineers (civil) may not have been working for mineral enterprises the inference from the statistics is doubtful. He makes the valid point, however, that the rapid development of curricula in civil and mechanical engineering undoubtedly had reacted to draw men into them who might otherwise have chosen the mining curriculum, and concludes by pointing out that enrollment was increasing at the Columbia School of Mines. If he had had access to the records of the other schools he would have been able to claim an even more rapid recent increase, especially in two or three of them.

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* This was a clerical error. Columbia did not then offer a mechanical curriculum.

Wellington would not be downed. He replied that: (1) the field of employment for mining engineers had been rapidly expanding for 20 years, (2) schools of mining engineering antedated those of mechanical engineering and were not far behind civil engineering, and (3) the demand for a mining engineering education "has of late been steadily falling off, not in one school, but at many schools; not for one year, but for many years." He concludes with a table of graduates of Massachusetts Institute of Technology showing that of the C.E. graduates 73.5 per cent are "still following their chosen branch of engineering," while only 50.4 per cent of the mining graduates were doing so. He arrived at these results by deducting the "chemists and metallurgists" who had taken the mining course, which was obviously unfair. The two sets of statistics cancel each other, and neither proves anything without a more careful study of the bases on which they were compiled.

While Wellington was completely wrong in his idea as to the average mining curriculum not being a good preparation for professional work, one must admit that the statistics did seem to justify his claim that the demand for a mining engineering education had been steadily declining. Of the 14 schools shown in his table 5 had already, in 1890, dropped, or were about to drop, their mining curricula; none but Columbia had ever* given as many as 10 mining degrees in a year, and the number of degrees given in 1890 was less everywhere than it had been in the eighties, except at Michigan College of Mines, which gave its first degrees in 1887. It was unfortunate for Wellington's reputation as a prophet that subsequent events demonstrated that mineral industry education, instead of sinking into a decline was, in 1890, on the threshold of a period of strong growth.

Christy's Arguments

A few other mining men also made rejoinder to Wellington's views on mining schools, but we must pass on to the paper "The Growth of American Mining Schools and their Relation to the Mining Industry" which S. B. Christy, who had been appointed professor of mining and metallurgy in the University of California in 1885, presented at the meeting of the American Institute of Mining Engineers held in connection with the International Engineering Congress at the World's Fair, Chicago, in August 1893. The full text of it is so easily available[12] that it is unnecessary to quote from it in extenso, but its main points may be recapitulated.

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* Massachusetts Institute of Technology gave 13 S.B. degrees in mining and metallurgy in 1884, but not more than 8 in any other year; no other school had given more than 7 degrees in one year.

After giving the official statistics as to the growth of the mineral industry between 1880 and 1891, and attempting to deduce from the census figures the total number of persons "engaged in mining and metallurgy" (0.63 per cent of the total population), he concludes from his statistics that the relative fields for mining, civil, and mechanical engineers in 1880 bore the ratio of 1:6:11. He shows that the ratio of graduates in 1892 from all schools was 1:7.73:9.27 and concludes that the developments of recent years were an attempt to remedy an acute shortage of mechanical engineers. Next he attempted to determine the number of trained men needed by the mineral industry, and arrived at the number 6000, which he compared with the membership of 2092 in the American Institute of Mining Engineers in 1892.

Next he calculated the annual openings for graduates of mining schools and concluded that they numbered 200 or "about four times as many openings as there are graduates to fill them." The remainder of the paper is taken up with discussing the question "Are mining schools justified?"; also, attendance at European and American mining schools, difficulties peculiar to American mining schools, and an attempt to forecast their future. He pays especial tribute to Professor Munroe for his development of summer practical work in mining "from what had hitherto been a mere summer jaunt without definite plan and purpose," and to Professor Richards for his development of laboratory work in ore dressing and metallurgy. He concludes by pointing out that there were then "twenty more-or-less endowed mining schools in America" and that 200 graduates annually could be turned out "by ten, or even better, by a half-a-dozen schools." In a footnote he argues that a single National School of Mines would not be able to adapt itself to local needs, nor to provide "the advantages secured from a healthy rivalry." He thought there should be twice as many schools to train mine foremen.

This paper was discussed by G. W. Maynard,[33] who pointed out that the short-lived mining course at Rensselaer Polytechnic had been omitted from the list of schools, and by George F. Swan, professor of civil engineering at M. I. T., who attacked the statistics as to the demand for mechanical engineers, which he thought were "entirely unwarranted." The basis on which the ratios for mining, civil, and mechanical engineers was calculated was certainly tenuous, and we now have better figures.

The enrollment in 122 engineering institutions in the United States in 1938–39 was divided as follows, according to the *Journal of Engineering Education*:[20] Mechanical engineering, 20,114; electrical engineering, 13,135; chemical engineering, 12,538; civil engineering, 10,585; mining and metallurgical engineering, 3536; total for all institutions reporting, 84,002. W. B. Plank's more complete survey,[45] which included petroleum technology, ceramics, and geology courses in mining schools, showed a total of 9619 students enrolled in mineral technology in 1938–39. Christy calculated that the number of civil engineering degrees granted in 1892 was nearly eight times that in mining; the figures in the *Journal of Engineering Education*[20] show 1572 bachelor's degrees granted in civil engineering 1937–38; while Plank records 1434 candidates for the bachelor's degree in mineral technology in 1939. Thus Wellington was wholly wrong in his ideas as to the future of mineral industry education, and Munroe and Christy, whose views follow, instead of being too optimistic, were actually too conservative. The growth of the mineral industry field in comparison with civil engineering is especially notable.

The longest discussion of the paper was by H. S. Munroe, who argued that Christy had underestimated the demand for mining graduates, because he had not "made sufficient allowance for the employment afforded by small mines and undeveloped mineral properties, especially in the West. These outnumber the productive properties ten to one." He next goes on to report on a questionnaire he had sent to 100 prominent mining men, of whom 70 had replied to the question "How do you account for the small demand, especially from the mining regions, for the instruction offered by our mining schools?" The consensus was that: (1) the demand for mining engineers is not large, (2) the entrance requirements are high and the course difficult, (3) the cost is high, (4) one can become a mine manager without a mining education, (5) life in mining regions is not attractive to young men who come from other regions, and other walks of life, (6) competition from other engineering curricula, and (7) prejudice in favor of practical men for responsible positions. Of these reasons, points 2 and 3 did not apply to some of the State-supported schools, but the others are generally pertinent. The remainder of his discussion need not here concern us, as it is largely a detailed description of his summer school of mining to which Christy had referred, and which has been described in chapter 8.

The results from human activities are sometimes quite different from those anticipated and hoped for. Christy had argued that one-fourth of the schools offering instruction in mining, already in existence, could supply enough trained men to meet the needs of the mineral industry, but what made an impression was his statement that there were openings in the industry for four times as many as were annually being graduated. Munroe thought this an underestimate of the openings, and this must have been the general opinion, for during the next two decades many new curricula were started; the schools initiated in the eighties, but which had not at first been able to do much, became more firmly established; and the attendance at the older schools generally increased. Instead of mining curricula going out of fashion, as Wellington believed, they were actually starting a period of renewed development, in most places. Registration in the Mining College, University of California, increased threefold in the decade 1893–1903, being 3 per cent of the University registration in 1893 and 11 per cent in 1903. It claimed,[8] at the latter date, to be the largest mining school in the world.

UNIVERSITY OF IDAHO

The University of Idaho was established by the territorial legislature in January 1889. The original institution consisted of three colleges: Arts, Letters, and Agriculture. The University catalogue for 1893–94 stated that the College of Arts was to provide instruction in mining and metallurgy, though no curricula leading to degrees were offered. In 1896–97 a curriculum containing 20 credits in mining, 10 in metallurgy, and 11 in geology and mineralogy, leading to the degree of bachelor of mining engineering, was offered. Edward Goodwin (E. M. Columbia, 1891), who had been an assistant in mineralogy at Columbia and later had wide experience in the West, taught all these courses, but left the next year and was succeeded by Alfred S. Miller, who remained there till 1905.

In 1901 a School of Applied Science was created, offering curricula leading to bachelor degrees in mining and civil engineering at first; in 1905 a curriculum leading to the B.S. in electrical engineering was added. In 1907 the name was changed to School of Engineering, and the courses in geology and mineralogy were transferred to the jurisdiction of the College of Letters and Science. A. C. Terrill was professor of metallurgy and W. R. Chedsey was associate professor of mining. In 1917 a School of Mines was established and the courses in geology and mineralogy were shifted back to it, where they have since remained. Francis A. Thomson, now president of Montana School of Mines, was brought from the Washington State School of Mines as the first dean of the new school. In addition to the mining curriculum, one was offered in geology leading to the B.S., and there was also a metallurgical option in the mining curriculum; differing only by a few credits in the senior year. In 1933 a curriculum leading to the B.S. in metallurgical engineering was offered. The geology curriculum was also differentiated into one leading to the B.S. in geological engineering and another leading to the B.S. in geology; the latter degree can be taken either in the School of Mines or the College of Letters and Science.

After a mining curriculum was first offered, in 1896, the enrollment of students in it was always a substantial fraction of the total enrollment of the University. The actual enrollment in the mining school was 13 in 1897–98, increased to 51 in 1908–9, then declined to 6 in 1915–16, and again steadily increased to 97 in 1936–37. A large assay laboratory building constructed in 1906 has since been converted into a geology building, and the metallurgical laboratory, built at the same time, now houses both the mining and metallurgical departments; space having been provided by the removal of large-scale milling and metallurgical equipment. This gradual development of mineral industry education in Idaho was more typical of the period than the rapid growth at the University of California.

WASHINGTON STATE COLLEGE

The Washington State College,* at Pullman, began work in 1891, a year sooner than Idaho, though it had not been authorized until a year later. Its first catalogue, 1892–93, offered four-year curricula, not given in detail, in mining, civil, mechanical and electrical engineering, and chemistry. Students in mining were slow in coming, one freshman appeared in 1894–95 and none in the next three years, but four entered in 1897–98. There was no definite curriculum in mining at that time, the mining instruction being given by the mechanical engineering department, and it was not till William S. Thyng (E.M. Columbia, 1895), who had been teaching mining at State College, Pa., was brought to Pullman as assistant professor of mining in 1899 that instruction in mining was put on a sound basis. He was succeeded by Royal P. Jarvis (A. M. Columbia, 1907) as professor of mining in 1908, who was in turn succeeded by Francis A. Thomson. In 1909 curricula in coal mining, metalliferous mining, and metallurgy were offered, courses in coal mining and washing were first offered. In 1917 it was organized as a School of Mines and Professor Thomson made dean, but he left the same year to become dean of the Idaho School of Mines and L. O. Howard succeeded him. In 1920 the geology department was transferred to the School of Mines, and the title changed to School of Mines and Geology. A. E. Drucker became its dean in 1926. In 1927 a mining geology option in the mining curriculum was offered in addition to curricula in metallography, mine management and petroleum engineering. In 1936 the curricula in mine management and petroleum engineering were dropped and the school now offers four-year curricula leading to the B.S. degree in mining and metallurgical engineering, with an option in physical metallurgy in the latter. From 1899 to 1929 the enrollment typically ranged between 20 and 40, since then it has ranged between 70 and 90, not including the geology students. The degrees granted in mining, however, never exceeded 5 per year before 1932, except in 1911, when 7, and 1914, when 6 mining degrees were granted. Since then about 15 mining degrees and two or three degrees in mining geology have been granted yearly.

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* See p. 141 for an account of the mining instruction at the University, at Seattle. Its original name was Washington Agricultural College and School of Science.

UNIVERSITY OF MINNESOTA

The School of Mines of the University of Minnesota was organized in 1892. The territorial legislature of Minnesota provided in 1851 that a University of Minnesota should be established near the Falls of St. Anthony. The panic of 1857 and the Civil War were the major reasons why actual academic instruction did not begin until September 1869, and the first degrees were granted in 1873. Three men took the degree of bachelor of civil engineering in 1876, the degree of bachelor of mechanical engineering was granted in 1878; both were granted rather infrequently before 1890, and the College of Mechanic Arts was not definitely separated from science, literature and the arts. Shortly thereafter the separation was made, and a College of Engineering, Metallurgy, and the Mechanic Arts was established. William R. Appleby, who had taken his A.B. at Williams in 1886, work at Columbia in 1887, and had four years experience in teaching and commercial work, was appointed professor of mining and metallurgy in the University of Minnesota in 1891.

The School of Mining and Metallurgy was formally opened in January 1892, as a subdivision of the College of Engineering and the Mechanic Arts. Four-year curricula leading to the degrees of E.M. and Met.E. were instituted. The first mining degrees were granted in 1894 and the first metallurgical degrees in 1901. Under Appleby's vigorous efforts, and the stimulus supplied by the rapidly increasing importance of mining in Minnesota, the school grew steadily, and after 1897 was recognized as an independent school with Appleby as its dean. In 1903 a School of Mines building was completed and occupied by the school. In 1909 an agreement was entered into with the State Tax Commission whereby members of the staff of the school checked all ore estimates submitted to the Commission by the various mining companies of the state. This state service has been carried on continuously since then.

In 1911 a curriculum in geological engineering leading to the degree of E.M. in geology was adopted, and a School of Mines Experiment Station was established to work in cooperation with the mining companies of the state on the problems of beneficiation of low-grade iron-bearing material and any other problems affecting the iron industry.

In 1913 the School of Mines building was destroyed by fire. A new building on a site nearer the engineering group was completed in 1915. The name of the school was changed in 1926 to School of Mines and Metallurgy, and in 1927 a course in petroleum engineering leading to the degree of E.M. in petroleum was adopted.

Upon the retirement of W. R. Appleby as Dean Emeritus in 1935, the School of Mines and Metallurgy, though preserving its identity, was affiliated with the College of Engineering and Architecture and the School of Chemistry to form the Institute of Technology with Samuel C. Lind as dean. E. H. Comstock was made directing head of the school. With the formation of the Institute of Technology the faculty voted to abandon the engineer degree, except as a graduate degree, and adopted the degrees: Bachelor of Mining Engineering, Bachelor of Metallurgical Engineering, Bachelor of Petroleum Engineering and Bachelor of Geological Engineering granted on the completion of a four-year curriculum.

The Pennsylvania State College

The Pennsylvania State College is remarkable as a land-grant college that had started even before the passage of the Morrill Act. The Pennsylvania Legislature in May 1857 authorized the establishment of the Farmers High School of Pennsylvania. A farm was started almost immediately, but there was delay in completing the building for instruction, which opened in February 1859. When the Morrill Act was passed, in 1862, Pennsylvania promptly accepted its provisions, and the name of the institution was changed to the Agricultural College of Pennsylvania. Its report for 1872 shows three curricula—agricultural, scientific, and classical. It is noteworthy that three of the eleven theses of the first graduating class of 1861 were on mineral industries problems, and that the first president of the College proposed a professorship of Agriculture, Chemistry and Geology and another of Metallurgy, Mining and Mineralogy in 1864. By 1874 the title had again been changed to The Pennsylvania State College.

Though it grew steadily, progress was slow. The report for 1880–81 shows 164 students in attendance, of whom two thirds were preparatory or special. A civil engineering curriculum appeared in 1884 and there was a further reorganization, in 1885, developing mechanical engineering instruction. The report for 1893 shows 200 students of collegiate grade in attendance, two thirds of them in the civil, mechanical, and electrical engineering curricula, and, oddly enough, only one in agriculture.

A department of mining engineering was authorized by the College Board of Trustees on Oct. 4, 1890, and in 1893 an appropriation by the state legislature provided $16,000 for its maintenance. Magnus C. Ihlseng, then professor at Colorado School of Mines, was appointed its head. Ihlseng had taken his E.M. at Columbia in 1875, and the C.E. and Ph.D. degrees there in 1877. He set up a four-year curriculum leading to the B.S. degree in mining engineering, with three options, beginning in the junior year, in mining, metallurgy, or geology. The plans for the department are set forth in some detail, and include a "Mining Bulletin," which was published six times yearly. Nine students were in attendance the first year. The 1894 report notes that a two-year short course in mining, and a 12-weeks course of winter lectures on mining had been started. H. B. Dowling took a degree in mining in 1894.

The School of Mines became a distinct unit of the College in 1896, when separate schools were first organized. The report for 1896 notes that three students had been graduated with the B.S. degree in mining, and that 24 were now in attendance, which, it is claimed, was one third of the total number of mining students then in Pennsylvania institutions. H. H. Stoek, who had been Ihlseng's assistant, resigned in November 1897, to take an editorial position with the *Colliery Engineer*, Scranton, and N. W. Shed was appointed as his successor. The report for 1899–1900 records that two of the teaching staff had been let go in a "retrenchment" program, and Ihlseng himself resigned during the year 1900–01, being succeeded by M. E. Wadsworth, who had been for 10 years president of the Michigan College of Mines, and previously had been instructor in mathematics and mineralogy at Harvard in 1877.

Wadsworth's first report (1901–2) makes the point that special attention should be given to the minerals actually being produced in Pennsylvania and complains that the two assistant professors were chemical graduates whose experience had been only in metallurgy and ore dressing, evidently not considering them real mining men. Because of Wadsworth's enthusiasm, or else the changes he instituted, attendance rapidly increased. It had hovered between 20 and 30, and in 1901–2 was no larger than it had been in 1894–95, but thereafter steadily increased until it reached 98 in 1905–6. In the decade 1894–1904, about 10 per cent of the graduating class were mining engineers. A new building was provided for the engineering departments in 1905–6, but mining was given space in an old wooden building, where it remained until the Mineral Industries building, the four floors of which total 76,000 sq. ft. of floor space, was completed in 1931.

Wadsworth resigned in 1909, to become dean of the School of Mines at the University of Pittsburgh, and was succeeded by Walter R. Crane, who had taken his A.B. and A.M. at Kansas, and his Ph.D. at Columbia in 1901. He had been assistant professor of mining at Kansas 1895–1905, and assistant professor at Columbia from 1905 to 1908. He resigned in 1918 to join the staff of the U. S. Bureau of Mines and was succeeded as dean by E. S. Moore, who had been professor of geology. C. E. MacQuigg, now dean of engineering at the Ohio State University, was made professor of metallurgy in 1912. When he left to become director of research for Union Carbide and Carbon Research Laboratories, David F. MacFarland was brought from the University of Illinois, in 1920, to head that work.

Dr. Moore resigned as dean in 1922, to go to the University of Toronto. He was succeeded by E. A. Holbrook (B.S. M.I.T., 1904), then assistant director of the U. S. Bureau of Mines, who previously had been on the staff of the University of Illinois. C. A. Bonine succeeded Moore as professor of geology. A ceramics engineering department was added to the School in 1923, with J. B. Shaw, of Ohio State University, as its head. The name of the school was changed to Mining and Metallurgy in 1924. During the same year courses in oil and gas geology and oil and gas technology were offered for the first time. Dean Holbrook resigned in 1927 to become Dean of Engineering at the University of Pittsburgh, and was succeeded in 1928 by Edward Steidle (B.S. Pa. State, '11), who had been head of the mining department at Carnegie Institute of Technology. Later developments are recorded in chapter 13.

University of Washington

Washington has two* State-supported institutions in which mining instruction is given, because the territorial legislature in 1855 provided for two universities, doubtless because of the natural eastern and western physiographic divisions of its area. Neither was started at the time and it was not until 1860–61 that one was definitely designated for Seattle if 10 acres of land were provided for a site. Three citizens provided the land and parts of two townships of land granted by the Federal Government in 1854 were sold to provide funds for the first building. Work began in 1862, but during its early years the University actually functioned chiefly as a primary and grade school. Its first academic degree was granted in 1876. In 1895 the institution was moved from its original site to one of 605 acres, 4 miles northeast of the center of the city, which was also improved in connection with an exposition held there in 1909. Meanwhile a School of Mining had been authorized in 1893, and Henry M. Landes began to give courses in assaying and mining after 1895. In 1898 three curricula were offered leading to the B.S. degree in mining engineering, the same with a geological option, and in metallurgical engineering. The first of these degrees was given in 1900, when the faculty of the School of Mines consisted of 13 professors and 6 instructors, with D. A. Lyon as dean. Milnor Roberts, who is still dean, succeeded Lyon when he joined the staff of the U. S. Bureau of Mines in 1901. In 1911 the title was changed to College of Mines. In spite of the effect on Seattle of the gold discoveries in Alaska in 1898, the School developed slowly and only one or two B.S. degrees in mining were awarded yearly before 1904; there were none in 1903. The first degree in the geological option was awarded in 1911 and the first B.S. in metallurgy in 1912. A curriculum in ceramic engineering was offered in 1918 and the first degree awarded for it in 1923. To June 1938 a total of 269 B.S. degrees had been awarded in these curricula, of which 40 were in metallurgical engineering and 23 in ceramic engineering. A large building provides laboratories for mining, metallurgy, ore dressing and coal washing, and ceramics, and also houses the Northwest Experiment Station of the U. S. Bureau of Mines. Research fellowships are offered and 59 M.S. degrees have been awarded; 18 in mining, 17 in metallurgical engineering, 21 in ceramic engineering, and 3 in mining geology.* The University now receives $100,000 yearly for the rental of its original site and about $250,000 from student fees, but its main support is derived from State appropriations. The endowment lands, though still retained, have ceased to yield much revenue, and what is obtained from them is put into a permanent fund, instead of being used for operating expenses. The College of Mines now offers curricula leading to the B.S. degree in mining engineering, in metallurgical, and in ceramic engineering. The professional degree has been awarded to 14 B.S. graduates, mostly in mining. A feature of the work is the annual Mining Institute meetings held for a week in January, at which popular and technical lectures and demonstrations are given, with a total attendance of 300 to 400 prospectors, miners, operators and engineers, investors, and other interested persons.

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* See p. 136 for the account of mining instruction at the State College, at Pullman.

Engineering at Harvard

In 1890 Harvard University was reorganized through the creation of a faculty of Arts and Sciences, which should have charge of the College and the Lawrence Scientific Schools. The Department of Engineering was put in the Division of Pure and Applied Mathematics and the Department of Mining and Metallurgy was assigned to the Division of Natural History. H. L. Smyth (Pumpelly's son-in-law) was appointed professor of mining and metallurgy in 1893 and a four-year curriculum leading to the degree of B.S. in mining was offered in 1894 (after 1896 it was mining and metallurgy). Under the new auspices the student body of the Lawrence Scientific School grew rapidly;

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* The geology department is not included in the College of Mines.

after 1902 it was exceeded in numbers only by the College and the Law School. One reason for this was the support derived from the estate of Gordon McKay, from which $1,000,000 was derived between his death, in 1903, and 1909; it has been estimated[37] that when the whole estate passes to the possession of Harvard in 1956 it will have amounted to $23,000,000. This munificent gift was for instruction in applied science and it is of interest to note that among the important assets of the McKay estate were the Conrey Mining Co.* and other mineral enterprises.

In 1903 the curriculum was again changed, and the Mining Engineer and Metallurgical Engineer degrees were awarded for a fifth year of graduate study after the bachelor's degree had been attained. In 1912 there was a further reorganization, which took the graduate school of applied science out of the Faculty of Arts and Sciences and created the Graduate School of Applied Science, with a faculty of its own. In 1914 a cooperative agreement with the Massachusetts Institute of Technology was entered into, and the Harvard Graduate Schools of Applied Science were dissolved. The story of the litigation as to whether such an arrangement complied with the terms of the McKay bequest can be found in "Development of Harvard University, 1869–1929," by S. E. Morison, and need not concern us here beyond noting that in 1918, after three years of engineering instruction under the joint administration of Massachusetts Institute of Technology and Harvard, a Faculty of Engineering was reestablished at Harvard, offering advanced courses of study in mining and metallurgy as well as in other branches of engineering. The degree of Mining Engineer was dropped in 1925 and that of Metallurgical Engineer in 1928, the M.S. and Ph.D. degrees (with designation of field) now being used. At first undergraduates were admitted to this Graduate School of Engineering, but since 1934 a bachelor's degree has been required for admission.

Since the present Harvard system is unusual, and not generally understood, a brief description of it may be useful. A bachelor's degree from "an institution of recognized standing" is required for admission to the Graduate School of Engineering. It may be an arts degree, and the statement of prerequisites says only that: "In general, mathematics through differential and integral calculus, and one or more courses of college grade in physics, chemistry, and engineering sciences are required." At the same time there is under the Faculty of Arts and Sciences a department of Engineering Sciences, consisting of a dozen men who are simultaneously members of the faculty of the Graduate School of Engineering, the dean of the School being chairman of the department. Under the Harvard system students "concentrate" in a field by taking at least six courses in a single department, but apparently it is not necessary to concentrate in engineering sciences to be admitted to the Graduate School of Engineering. Statistics on candidates for the bachelor's degree in engineering at Harvard refer to those students in Harvard College who are "concentrating" in engineering sciences. Speaking of the later reorganizations of the Lawrence Scientific School, N. J. Hughes, dean of the Harvard Engineering School, expressed the following views (ref. 37, pp. 431–33):

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* The Conrey Placer Mining Co. operated in Montana from about 1898 to about 1916; then, the available gravels in Alder Gulch having all been worked, the operation was closed and the dredges were junked or salvaged. According to U.S. Bureau of Mines *Bulletin* 121 (p. 8), Harvard received about one million dollars as a result of this operation, which went out of existence about 15 years ago.

> The abolition of the four-year programmes of the Lawrence Scientific School has proved to be a costly mistake. The resulting loss of clientele has not yet been recovered, to say nothing of the sacrifice of the development that would have taken place if the Graduate School had been built upon the then excellent undergraduate work of the Lawrence Scientific School, as Shaler and Hollis urged. Indeed, the legislation of 1906 definitely provided such a plan; but the foundations for a sound development were removed by abolishing the undergraduate programmes in 1907, the year following Shaler's death.
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> Eliot's ideal of a school for graduates of colleges and scientific schools was shared by many members of the Faculty. They believed that the demand for engineers would greatly increase, especially in industry, which was already developing with great strides; and that the best education was a long university course ending in highly specialized study. The growth in the demand for engineers did far exceed any possible expectations; but the demand was for Bachelors not Masters in engineering. The expectation that the engineer of the future would function largely in a professional capacity was based on a mistaken forecast of the demand of industry for scientifically trained men. Engineering graduates in increasing numbers have been taken into industry, where many are filling positions of responsibility, scientific, technical, or administrative; but engineering graduates have reached such positions only after considerable experience and practical training in the industries themselves. There is also an increasing demand for specially trained experts in design, research, teaching, and advice;

but all positions of this character would probably not employ more than a quarter of the engineering graduates.*

Engineering graduates seldom enter directly upon an individual professional career, and even in private practice they must usually function as a part of a large organization. Experience and practical training, as well as post-graduate study, are necessary, even for those who are to become experts in research and design. For the larger group who will eventually fill positions involving executive responsibility, a considerable time must be allowed after graduation for training in technique, and for personal adjustment to actual working conditions which cannot well be taught in the classroom. Hence the four-year engineering curriculum has come to be generally accepted as the norm, and the small number enrolled for graduate study in applied science up to 1914 is easily understood.

Since the foregoing paragraphs were written, the Department of Engineering Sciences has grown into a strong unit in Harvard College, and a practically minded student, who knows what he wants as a freshman, can select a program of study in this field that would be almost as well packed with sciences and engineering principles as the curriculum of a strictly technical school. But, in line with Harvard's insistence on the importance of the "liberal" education in the College, undergraduate students interested in engineering are not allowed to give their attention entirely to subjects closely related to their chosen profession but to include a variety of studies in other fields, such as literature, history and economics, during their college years.

The plan is an effort to place engineering studies at Harvard on the same basis as law and medicine, and to postpone the strictly professional instruction until the student has received the benefits (or otherwise) of a liberal education in the College. It is a good plan for some, and certainly should produce a more broadly cultivated man than the usual technical course, but it requires more time than most students can afford. Few engineering students have much interest or aptitude for studies outside of science and its applications, and diversion in entertaining, intellectual byways sometimes has a harmful effect.

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* There are more than one hundred and fifty engineering colleges in the country today [1930], with an enrollment of some sixty thousand students, about 85 per cent of them being enrolled in Civil, Mechanical, and Electrical Engineering, Mining, and Metallurgy, and Chemistry. Fully two-thirds of the graduates of engineering schools during the last thirty years are now filling executive or supervisory positions; and younger men in increasing proportion are preparing themselves for that kind of work. Nearly 98 per cent of the students enrolled in the engineering colleges of the present day are studying for a Bachelor's degree, and only a few of them have previously graduated from a college of liberal arts.

Graduate Instruction Costly

Columbia's experience with putting mineral industry instruction on a graduate basis is described in the next chapter; that of Stanford follows later in this chapter. The conclusion from these educational experiments is that only an institution that is financially very strong can stand the increased cost of such instruction, resulting from reduction in enrollment and the maintenance of expensive laboratories for advanced work. The departmentalization of large educational institutions also leads to lack of contact between men working in overlapping fields but in different departments, and advanced workers are seldom either able or willing to teach beginning courses. The general articulation between curricula leading to the B.S. degree and advanced degrees, throughout the country, is not at all good and much progress in academic organization, in the writer's judgment, still remains to be made.

University of Pittsburgh

The University of Pittsburgh, originally chartered as Pittsburgh Academy in 1787, and reincorporated as the Western University of Pennsylvania in 1819, began to give separate degrees for engineering students after 1868. Apparently there was engineering instruction before that; as early as 1846 there were two graduates who probably received degrees in engineering. Later, all University records were destroyed by fire. After Daniel Carhardt went to the institution as professor of civil engineering, in 1882, effective growth began and in some later years four-fifths of the yearly graduates were engineers. There was little interest in mining engineering education among the leaders of the coal industry of western Pennsylvania, so that it was not until 1895 that formal courses in mining were attempted at the University. In that year the state legislature authorized "a department to be known as the Western Pennsylvania School of Mines and Mining Engineering" and gave the University $50,000 for building and equipment; local people in Pittsburgh raised an equal amount. The institution at that time was in

Allegheny. In 1896 W. G. Wilkins and Selwyn M. Taylor were appointed professors of mining engineering.

By the early 1900's it was clear that the University should be in the city of Pittsburgh rather than in Allegheny City (now the north side of Pittsburgh) and in 1906 it began moving to the hillside site it had secured in the Oakland district. The completion of this move was signalized by the change of its name to the present form in 1908. Meanwhile the School of Mines received effective organization and M. E. Wadworth, who had been president of Michigan College of Mines for 12 years, and was then at Penn State as professor of mining, was brought in as its first dean. H. C. George was instructor in mining from 1904 to 1907; in 1933 he returned as head of the department of Petroleum and Gas Production. S. L. Goodale (E. M. Colo. School of Mines) became professor of metallurgy in 1909. After Wadworth retired, in 1912, S. A. Taylor was acting dean for a time. H. B. Meller, who was instructor in mining from 1910 (the year he graduated), was dean of the School from 1914 to 1923. R. M. Black (B.S. Harvard) became professor of mining in 1914.

From 1914 to 1923 the University grew rapidly. So great was pressure of students in other schools that in 1919 the School of Mines was moved into temporary war buildings on the edge of the campus, and it was not until 1935 that permanent quarters were again established for the school. In 1923, F. L. Bishop was made dean of the School of Mines as well as that of Engineering. In 1927 E. A. Holbrook (B.S. M.I.T., 1904) then dean of the School of Mines at Penn State, was brought in as dean of the two Schools of Mines and of Engineering. The first degree in metallurgical engineering had been granted in 1910. In 1925 a degree was given in petroleum refining. In 1913 the department of oil and gas was started under Roswell Johnson. This was the first department of its kind in the United States. The enrollment in the School of Mines in 1937–38 was the highest in its history, 226 undergraduate students. It now offers four-year curricula leading to the B.S. degree in mining, metallurgical and petroleum engineering, and in petroleum geology.

Since 1927, three master's degrees have been granted in mining engineering; four master's and one Ph.D. degree in metallurgical engineering; and thirteen master's and two Ph.D. degrees in petroleum and natural gas engineering. In 1939 some 50 students were enrolled for graduate work in the School.

STANFORD

The history of mineral industry education at Leland Stanford Jr. University,* established as a memorial to a 15-year old boy, is of much interest. The donors had at first been undecided whether to provide a technical school of civil, mechanical, and mining engineering, an institution at San Francisco with museums and free public lectures, or a University at Palo Alto. The final endowment grant provided† for "a university for both sexes, with the colleges, schools, seminaries of learning, mechanical institutes, museums, galleries of art, and all other things necessary and appropriate to a university of high degree." Leland Stanford's idea was to get the most distinguished educator in the country as president and the outstanding men in every line for the faculty by the simple expedient of offering them higher salaries than they were receiving.‡ He was somewhat taken aback to have Andrew D. White reply "not for all the wealth of the Pacific Coast would I go through the wear and tear of again seeking to establish another university. . . . "

In the first plans for selecting a faculty it was decided to give equal prominence to liberal arts and pure science, and applied science. The buildings were completed and opened for academic work on Oct. 1, 1891. It had been announced that tuition would be free, good board and lodgings would be provided for $4.50 per week and students from every quarter of the globe would be welcome. More students were admitted than the University of California enrolled that year, after almost a quarter century of growth. The first faculty appointments were made with the expectation that nearly all the students the first year would be freshmen, but it was understood that a professor of mining would be needed in a year or two. Actually almost 20 years elapsed before a full professor of mining or metallurgy was appointed.

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* The name has been changed to "Stanford University."

† Actually the University owned nothing at first but its buildings and unproductive land. The operating expenses were currently provided by Stanford.

‡ For a fuller account of this, see pages 148–153 of "Across the Busy Years," by Nicholas Murray Butler.

It is difficult to determine exactly why that happened. The great influx of students whose main interest was in liberal arts and pure science made a greater demand on resources than had been anticipated. President Jordan's major interest was in pure science, and a large proportion of his first faculty appointments were in that field, but there were also two engineers (C. D. Marx, civil engineering, and H. B. Gale, mechanical engineering) among the first 15 appointees. The first man offered a professorship was John Caspar Branner, a graduate of Cornell, then professor of geology at Indiana University and acting as State Geologist of Arkansas, but he did not go to the institution until February 1892. Leland Stanford's death in June 1893 brought financial embarrassment and the year 1893–94 was one of retrenchment and salary cuts. The Government brought suit against the Stanford estate and Mrs. Stanford said in May 1895 that if the decision should go against the estate the University would have, so far as she could see, to close. Probably this was why mining and metallurgical departments were not established according to the first plans, but the work was at first given by the geologists and later by men of junior rank who academically were members of the geology department.

The results thus obtained were excellent. H. C. Hoover graduated with an A.B. degree under the first system, and under the second such men as Dorsey A. Lyon, G. H. Clevenger, and L. W. Bahney taught metallurgy; A. F. Taggart was assistant to J. F. McClelland, who taught mining from 1908 to 1910 and was made the first full professor of mining the last year he was there. The years after 1905 were a period of revamping the entrance and curriculum requirements. Branner became president of the University in 1913, and was succeeded by Ray Lyman Wilbur in 1916. The latter believed that the rapid growth of junior colleges in the West would eventually bring the universities into hopeless competition with them, being forced into an upper division and graduate status, and making the A.B. degree unattractive to university students. He also felt that training beyond the A.B. degree is essential for the professions of engineering, law, and medicine. When Theodore Hoover was called to

Stanford in 1919 as head of a mining and metallurgical department, he shared that view and there was substituted for the four-year mining and metallurgical curriculum a two-year one following an A.B. degree taken in a curriculum which was three-fifths stipulated and two-fifths optional. After 1925 the University was reorganized into Schools of Physical Sciences, Letters, Biological Sciences, Business, and Engineering, Mr. Hoover becoming dean of the latter and all engineering instruction being put on the basis described.

J. M. Hyde, W. J. Crook, W. F. Dietrich, and F. G. Tickell (now executive head of the department) were added to the teaching staff. No stipulated curricula are required for the two graduate years, which, according to the courses selected, lead to engineering degrees in mining, metallurgical engineering, or petroleum engineering. No other institution has exactly this academic organization. Its obvious drawback is that geology and mining are in separate academic compartments and prospective mineral industry students, faced with the necessity of taking a large number of engineering courses, find difficulty in making early and sufficient contact with geology and mineral technology courses. It has been proposed to establish a School of Geology and Mining, in which mineral technology and applied geology would be brought together in order to remedy this condition. Enrollment (graduate) in the mining department has in recent years ranged from 12 to 23, with a slightly larger number in geology upper division work.

University of Kansas

The first beginnings of mineral industry instruction at the University of Kansas are obscure. Its engineering school was established in 1870, and for some time previous to 1900 Erasmus Haworth had the title of professor of mining engineering as well as of mineralogy and geology; he was also State Geologist. A definite four-year curriculum leading to the degree of B.S. in mining engineering was established in 1898 and the first class in it was graduated in 1902, Frank E. Marcy being among the members. At the same time metallurgical instruction was offered by the chemistry department, and eventually was established as a metallurgy option of the B.S. degree in chemical engineering.

Walter R. Crane, who had taken his A.B. and A.M. at Kansas, and the Ph.D. at Columbia, was assistant professor of mining from 1895 to 1905, and was succeeded by C. M. Young. The department of mining was separated from geology in 1915.* In 1924 instruction in petroleum engineering was offered by the mining and mechanical engineering departments. In 1937 petroleum engineering was made a separate department (see p. 195) and metallurgy was transferred to the mining department as an option in the mining curriculum. Since 1900 the school has given a total of 163 mining and metallurgical degrees, or an average of a little over four per year.

OREGON

In Oregon the 90,000 acres of land conveyed under the Morrill Act was to be sold; the interest on the funds thus derived was directed by the legislature to be given to Corvallis College, then a Methodist Church South institution. By 1885 this had become wholly a State institution and its name was changed to State Agricultural College. Though provision was made for instruction in the "mechanic arts" most of the graduates prior to 1900 are recorded in the alumni register as being either teachers or farmers. The announcement for 1899–1900 has a loose four-page insert headed "School of Mines of the Oregon Agricultural College" and records that "The professor of geology and the professor of mining engineering are now (August 1900) visiting the various mining districts of Oregon," and adds that "they expect to be accompanied by the advanced students of this department." The professor of geology was a graduate in chemistry of the College in 1892, and the professor of mining a civil engineer. Thereafter a four-year curriculum in mining engineering appears in the announcements; its elementary character is indicated by the students taking analytical geometry in their junior year. Henry M. Parks, who had taken his B.S. degree in mining at Iowa State in 1902 and was at the time assistant professor of mining and metallurgy at Northwestern University, was brought in as professor of mining in 1908, and built up the work until, with two associates, he was responsible for some 36 courses, ranging from physiography to ceramics, and including mining, ore dressing and metallurgy. Originally the school was housed in a small frame structure, but a four-story brick Mines building was constructed in 1911–12 and the work was organized as a School of Mines, with Parks as dean, in 1914–15. He resigned in 1917 to become State Geologist, and was succeeded as dean in 1918 by E. K. Soper, who had taken his Ph.D. in geology at Minnesota in 1917 and was associate professor of mining at Idaho in 1917–18. He soon left to take a position with S. Pearson & Son, Ltd., as petroleum geologist, and was succeeded by Charles E. Newton in 1919. Dean Newton remained in charge until 1928, when he was succeeded by J. H. Hance, who had taken his E.M. at the University of Washington in 1910, and his Ph.D. at Chicago in 1918. During the last year of its existence the school offered four-year curricula leading to the B.S. degree in mining engineering, metallurgical engineering, and geology and mining, giving the E.M. or M.S. degree for the completion of a fifth year. Eight such degrees were awarded in June 1932.

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* An attempt to establish a State School of Mines at Wier City, about 1913, did not succeed.

In June 1932, the State Board of Higher Education abolished the School of Mines, the official reason given being the urgent need for economy during the depression, all the state institutions in Oregon being consolidated under a single governing board. The geology and mineralogy work was transferred to the School of Science, mining was made a department in the School of Engineering, where it still continues, and metallurgy was dropped. No degrees in either mining or metallurgy have been given since 1932.

University of Kentucky

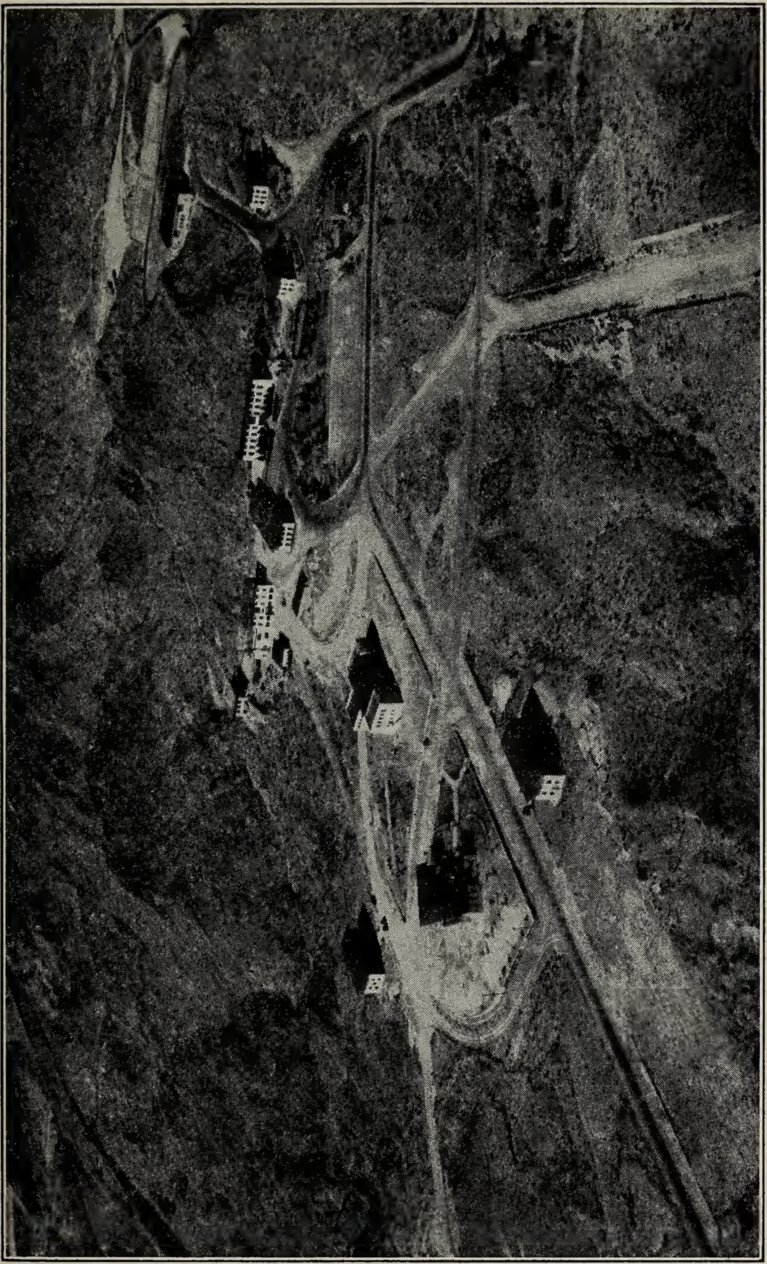
At the University of Kentucky a College of Civil Engineering was established in 1886, which was followed by a College of Mechanical and Electrical Engineering in 1891. In 1901 C. J. Norwood, a most remarkable man who served also as chief of the State Department of Mines and as State Geologist, organized a College of Mining Engineering, of which he became dean. In 1917 these three Colleges were merged into a single one of engineering with F. P. Anderson (mechanical engineering) as dean. Norwood remained head of the mining and metallurgical department until his death in 1927, when it was divided into two, with C. S. Crouse as head of the metallurgical work and T. J. Barr in charge of mining. On Barr's death in 1929, the two departments were again united, with Professor Crouse as head. In the earlier period coal mining was emphasized, and there were no graduates in metallurgical engineering until 1920. At present there is quite as much student interest in metallurgy as in mining, and in a new building, recently completed, admirable laboratory facilities for this work have been provided. The department now offers four-year curricula leading to the B.S. degree in metallurgical and mining engineering. Masters' degrees are given under the usual conditions for resident work, and the Engineer degrees are awarded for outstanding work done in industry after the B.S. degree has been attained.

Texas

Stephen F. Austin, while a member of the Legislature of Missouri, had drafted a memorial to Congress urging it to make provision for a school there (see p. 21). When he established the first American colony in Texas in 1821, at the place that bears his name, he was still concerned about education, and in April 1829 he wrote J. H. Bell that there was "over $1300 subscribed" for an academy. He also drafted a plan for an Institute of Modern Languages at Austin, probably in 1831–32. Under the Republic of Texas seven universities were authorized, one at San Augustine in 1830, another at Galveston in 1841, a third at Marshall in 1842, Hermann University in 1844, and Baylor, Matagorda and Nacodoches Universities in 1845; most of these were granted State lands with their charters, but except for Baylor none of them developed into anything. The subsequent history of education in Texas is so complex that there are two books[5,17] which consist merely of source material on the subject, and also a legislative report.[24]

What concerns us may be summarized by saying that an Agricultural and Mechanical College was established at College Station, Brazos County, in 1871 and formally opened in 1876. Unlike most other State agricultural colleges, it never attempted to give any mineral industry instruction until it introduced a curriculum in petroleum engineering about 1928 (described in more detail on p. 200). Governor O. M. Roberts urged the creation of a State University after he was elected in 1878, and the final action taken in 1881 was to establish it at Austin, with its medical department at Galveston. The University graduated one bachelor of arts in 1884–85 but there were no engineering graduates until 1893–94, when one C.E. degree was given. An announcement of a course in mining appeared in the catalogue for 1900–1901, and after William B. Phillips went there in 1902–3, a School of Mines was established, with a curriculum leading to the Engineer of Mines degree. One such degree was given in 1905–6, and never more than three in subsequent years. Phillips was succeeded by C. E. Rowe, instructor in mining, in 1907. Professor Rowe was made head of the Drawing Department, and mineral industry instruction at the State University at Austin was dropped in 1913 when the state legislature created a State School of Mines and Metallurgy, as a branch of the University, at El Paso. The new institution began work there in September 1914 in the buildings of the old Military Institute. These burned down in 1916, and an appropriation of $100,000 by the legislature provided new ones on a better site of 23 acres, on the west side of Mt. Franklin. S. H. Worrell was appointed its first dean, and was succeeded by John W. Kidd (E.E. Texas A. and M., 1909). Charles A. Puckett later became dean, with Professor Kidd as director of mining and metallurgy.

Reacting to the needs of its environment, the new school developed not only mineral industry education but instruction in the general field as well. It absorbed the El Paso Junior College in 1927, and now has a four-year curriculum leading to the bachelor of arts degree, with provisions for majoring in science, economics, business administration, education, English, history, journalism, music and modern languages. It also gives two years of work toward any of the engineering degrees in the University at Austin as well as preparing for entrance to its law school, and gives three years of work that is accepted for the B.A. at the end of one more year's work at the University Medical School at Galveston. It also offers educational work leading to State teachers' certificates. It is coeducational, and there are evening and summer session classes. John G. Barry (S.B. M.I.T., '07) became its first president, and professor of economic geology and



Texas College of Mines and Metallurgy, El Paso.

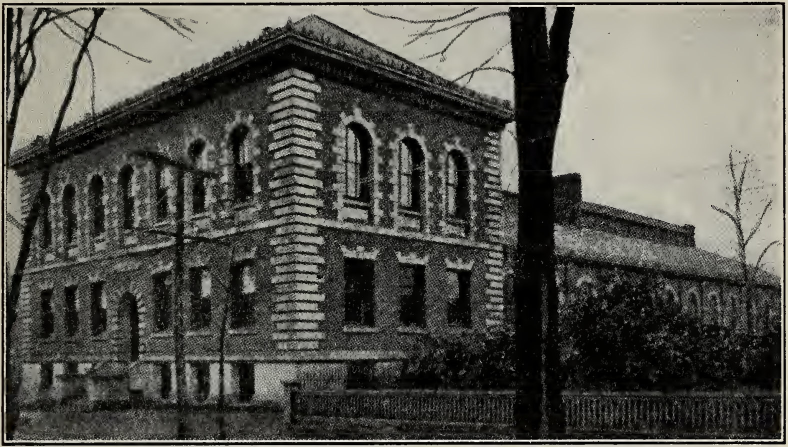
mining in 1931 and he was succeeded by D. M. Wiggins as president in 1936. John F. Graham (B.S. M.C.M., '05) is professor of mining and metallurgy. A four-year curriculum leading to the B.S. in mining engineering, with options in metallurgical engineering and mining geology and petroleum geology, is offered. Nine mining degrees were granted in 1930–31.

Mineral industry education was resumed at the State University in Austin during 1927–28 when a curriculum leading to the B.S. in petroleum engineering began to be offered. Since this is described in some detail on p. 200, no more need be said about it here.

YALE UNIVERSITY

Interest in mining instruction at Yale also had a revival about 1900, and it was decided to supplant the bare announcement in the catalogue that students who had completed the (three-year) course in civil or mechanical engineering could take a fourth year "in the study of metallurgical chemistry, mineralogy, etc.," with definite curricula in engineering preparatory to mining, and in chemistry preparatory to metallurgy. Eleven students elected these two courses the first year, and an immense impulse was given to the movement in 1903, when John Hays Hammond (Yale, 1876) announced that he would give the University a large metallurgical and mining laboratory. Hammond was appointed titular professor of mining engineering, Louis D. Huntoon (E.M. Columbia, 1895) was made assistant professor of mining and metallurgy in 1904, and advanced to full professor in 1908. The laboratory was completed in 1906.

So far what had been offered were three-year Ph.B. curricula in mining and metallurgy. In 1907 Yale offered a two-year graduate curriculum, to follow the Ph.B. one, and lead to the Engineer of Mines degree. Most of the work was not in any sense graduate, including as it did such subjects as surveying, thermodynamics, elementary mechanical and electrical engineering, and mineralogy and geology. There was no professor of economic geology at Yale until 1907, when John D. Irving was appointed to the chair. In 1909 James F. McClelland, who after his experience at the University of Wyoming had taught mining at Columbia and Leland Stanford, was made professor of mining engineering. In 1910 the two curricula were recast into a single five-year curriculum leading to the degree of Mining Engineer. In 1911 C. H. Mathewson was made assistant professor of metallurgy and L. W. Bahney assistant professor of mining and metallurgy. Mathewson was a Ph.D. in chemistry and metallurgy from Göttingen and had taught metallurgy at Massachusetts Institute of Technology. At the same time a five-year curriculum leading to the degree of metallurgical engineer was announced. Arthur F. Taggart was made assistant professor of mining engineering. Murray Guggenheim gave $20,000 in 1912 as an endowment fund for mining and metallurgy.



Hammond Laboratory, Yale University.

The World War had the same effect at Yale that it had at other places; also, McClelland left in 1919 to become associated with banking. Taggart also left to go to Columbia, and his work was taken over by Robert K. Warner, who was made assistant professor of mining in 1921 and remained until 1934. Mathewson was made full professor of metallurgy in 1922, but McClelland's place was not filled till 1926, when B. B. Gottsberger (E. M. Columbia, 1895) was appointed professor of mining. H. A. Behre taught ore dressing from 1925 to 1930.

In 1933 the engineering courses were set off from the Sheffield Scientific School as a separate School of Engineering, with four-year curricula leading to the B.S. degree in the respective branches of engineering, and provision for obtaining the engineer degree by not less than one year of additional advanced work. Though in 1911–14 the major student interest had been in the mining engineering curriculum, after the World War the position gradually reversed. This was so markedly the case that when Professor Gottsberger resigned in 1931 his position was not filled and the curriculum leading to the B.S. degree in mining engineering was officially dropped in 1934. In the student group tributary to Yale there is apparently not enough interest in mining to support a mining engineering curriculum. It is interesting, however, that Yale should, after so many years, develop high-grade and thriving work in metallurgical engineering. This will be further discussed in dealing with the development of metallurgical education.

West Virginia

The Agricultural College of West Virginia, established at Morgantown in 1867 by the state legislature, had previously been the Monongalia Academy and the Woodburn Female Seminary. The legislature changed the name of the institution to West Virginia University in 1868. The first degree (A.B.) was granted in 1870. Until 1882 engineering instruction was given in the fourth year of the scientific course. Geology was offered with the first scientific instruction and this work was much strengthened by Dr. I. C. White during his professorship of geology, from 1881 to 1890. A College of Engineering and Mechanic Arts was established in 1887, in which there was a School of Civil and Mining Engineering under Prof. T. M. Johnson. For the following eight years one course in mining was offered, but was then discontinued because, through a change in staff, no one was available to teach mining. Thereafter an option in mining was offered in the senior year, but not on an organized basis, as it was worked out to suit each case. Also, during this period (1895–1905) work in mine surveying was continuously offered as part of one of the civil engineering surveying courses.

In 1906 a department of mining engineering was established in the College of Engineering, with Henry Mace Payne as professor of mining engineering, and a mining engineering curriculum was organized. Professor Payne was succeeded in

1910 by R. B. Brinsmade (Washington University 1894, B.S.) who in turn was succeeded on his resignation in 1912 by E. N. Zern (Pennsylvania State College, B.S., E.M.). Professor Zern greatly increased the facilities of the mining engineering department and in 1913 started the mining extension program for the coal miners of the state, which is described at greater length on p. 255. In 1912 he also placed the oil and gas option in the curriculum. In 1917 Professor Zern resigned to become editor of the Keystone Catalog, and was succeeded by A. C. Callen (E.M. Lehigh, 1909) as professor of mining engineering and director of mining extension. Professor Callen further increased the scope of both engineering and extension work in mining, but resigned in 1924 to go to the University of Illinois. He was succeeded by C. E. Lawall (E.M. Lehigh, 1914), who was already on the mining faculty.

In 1926 the state legislature authorized the separation of the School of Mines from the College of Engineering and that was done in 1930, with Professor Lawall as director of the School. The mining engineering and extension work steadily increased in enrollment and facilities. In September 1938, Professor Lawall was appointed acting president of the University, and subsequently appointed president in July 1939. Dr. Lawall also continued as director of the School of Mines until September 1939, when D. L. McElroy (B.S., E.M., West Virginia University, 1927) was appointed director.*

The School of Mines now offers a four-year curriculum in mining, with options in coal mining, and oil and gas, leading to a B.S. degree in engineering of mines. There is also a five-year curriculum leading to a B.S. degree at the end of the fourth year, and a B.S. in engineering of mines at the end of the fifth year. The freshman year in the School of Mines is the same as that in the College of Engineering.

Virginia Polytechnic Institute

Virginia Polytechnic Institute, the land-grant institution for that state, was established at Blacksburg in 1872. Unlike most other land-grant institutions, it did not at once attempt to establish a curriculum in mining engineering, and gave no more instruction in metallurgy than might be presented in inorganic chemistry courses. The department of geology and mineralogy was established in 1902 and in 1905 a curriculum in applied geology was offered. A separate department was created for metallurgy, more courses were added, and a curriculum leading to the B.S. degree in metallurgy was established in 1907. In 1908 a curriculum in mining engineering was organized and a department of mining engineering created in the School of Engineering. The departments of geology and metallurgy were in the Science College until 1930, when geology was transferred to Engineering, more engineering was introduced into the geology curriculum and its name was changed to engineering geology. In 1934 the metallurgical department was transferred to the School of Engineering, its curriculum revised, and its title changed to Metallurgical Engineering. Meanwhile a Department of Ceramic Engineering had been organized in 1928 and the next year a ceramic option in the mining engineering curriculum was offered. In 1934 a four-year curriculum in ceramic engineering was established. A modern building for "mineral industries" was erected in 1939–40.

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* He is also director of the Fire Service Extension School, organized in 1931 in cooperation with the State Fire Marshal to bring about a reduction in fire losses in the state.

UNIVERSITY OF OKLAHOMA

The University of Oklahoma was established by the territorial legislature in 1890, and began work at Norman in 1892. Beginning with a course in surveying in 1899, the first two years of an engineering curriculum were established in 1900, and in 1902–3 a curriculum in civil engineering was offered and a School of Mines was organized. In 1904 the curricula in other engineering subjects were organized as a School of Applied Science. In 1909 these two schools were combined into a College of Engineering that in its present development consists of 11 schools, among them Chemical Engineering (petroleum-refining option), Geological Engineering, Mining Engineering, Natural Gas Engineering and Petroleum Engineering. All curricula have a uniform freshman year. The four-year curricula in geological engineering and mining engineering, leading to the B.S. degree, are the same for the first two years, after which the mining curriculum substitutes metallurgy and engineering subjects for the geology in the other curriculum. Two courses in the mining field are listed, with the notation that they will be offered as soon as conditions warrant. For the curricula in the petroleum field see p. 195.

University of Wisconsin

Instruction leading to mining and metallurgical engineering degrees was revived* at the University of Wisconsin in 1908 by the appointment of Edwin C. Holden as professor of mining and metallurgy in the College of Engineering. He had taken his E.M. degree at Columbia in 1896, had served as an assistant there for one year, and subsequently had a wide range of operating experience, especially in British Columbia and Arizona. A four-year curriculum in mining and metallurgy leading to the B.S. degree in mining engineering was then offered and the department's laboratories were established in the old heating plant, which was remodeled for this purpose. F. T. Havard was appointed associate professor of mining and metallurgy in 1909. In 1914 R. S. McCaffery was appointed professor of mining and metallurgy to succeed Professor Havard, who had died in the previous year.

During this period the department offered courses in two major options, mining engineering and metallurgical engineering, and cooperated with the department of geology in the conduct of a third (geological) option, all leading to the B.S. degree in mining engineering. In 1921 the department was authorized to grant the B.S. degree in metallurgical engineering to those students majoring in that option and to continue the B.S. degree in mining engineering for those students majoring in the mining and geological options.

E. R. Shorey was appointed assistant professor of mining and metallurgy in 1919, promoted to associate professor in 1927, and made professor of mining and metallurgy in 1938 when McCaffery retired. George J. Barker was made instructor in mining and metallurgy in 1921 and promoted to assistant professor in 1923. Joseph F. Oesterle was made assistant professor of mining and metallurgy in 1921, and promoted to associate professor in 1937.

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* See pp. 72–74 for early developments.

Scott Mackay, appointed associate professor of metallurgy in 1927, left in 1935 to go to Rensselaer Polytechnic Institute.

With the growth of the department, its facilities became inadequate, and in 1932 a building was assigned to it that provides well-equipped laboratories and excellent facilities for research. The department continues to offer the options in mining and metallurgical engineering and to cooperate closely with the department of geology in the geological work, offering degrees in mining and metallurgical engineering, both the B.S. and M.S. It conducts off-campus courses of graduate grade in Milwaukee, which lead to the M.S. degree in metallurgy. Resident graduate study and research are actively fostered.

University of Notre Dame

At the University of Notre Dame, Knowles B. Smith (E.M., M.C.M., '02; Ph.D. Notre Dame, '17) was engaged in 1908 to organize a department of mining engineering to supplement its already existing engineering instruction. The curriculum, in a predominating academic atmosphere, was planned to stress academic training with a wide choice of elective subjects under the supervision of the head of the department. Until 1925 the degree of Mining Engineer was conferred; after that the B.S. in mining engineering was given. In 1933 Edward G. Mahin (B.S. Purdue, '01; Ph.D. Johns Hopkins, '08) was appointed professor of metallurgy and head of that department, and a curriculum leading to the B.S. degree in metallurgy was established.

In 1940 mining engineering was discontinued as a degree-granting department and Professor Smith became professor of geology in the department of science.

Carnegie Institute of Technology

The Carnegie Institute of Technology was founded in 1900, and began work in 1905 as the Carnegie Technical Schools. In 1912 it was reorganized under its present title as four colleges—Engineering, Industries, Fine Arts, and one for women. Fred Crabtree was made head of a department of mining and metallurgy in 1909. The 1910–11 announcement offered three curricula in metallurgy—iron, nonferrous, and electrometallurgy; and two in mining—coal mining and metal mining. C. T. Griswold, who had been teaching mining at Colorado College since 1907 (see p. 169), was appointed assistant professor of mining in the autumn of 1911. Griswold left in 1915 and was succeeded by Joseph Jensen (B.S. Utah, '08; graduate work at Freiberg, 1911–12; M.A. Columbia, 1913). Edward Steidle (B.S. Penn State, 1911) became head of a separate department of mining in 1919, with Robert Z. Virgin, who had been assistant director of the mining extension work at West Virginia University, as assistant professor of coal mining, and L. H. Dougherty (C.E. Pittsburgh, 1902) as assistant professor of mining. Dougherty died the next year and was succeeded by L. W. Huber (B.S., 1921; M.S., 1923, Univ. Ill.). Harold J. Sloman (E.M. 1917, Lehigh), now assistant professor of mining engineering at the University of Alabama, was at Carnegie Tech. from 1924 to 1936. Virgin left in 1924 and Huber in 1927.

While Steidle was there especial attention was paid to cooperation with the coal-mining industry. In 1919 a Mining Advisory Board, consisting of more than a dozen high officials of coal-mining companies, representatives of the U. S. Bureau of Mines, and others, was organized, with Steidle as its secretary. This Board sponsored the publication of 45 cooperative bulletins on mining, fuel technology, and related subjects, and 77 research fellowships were financed, nearly 100 coal-producing companies contributing over fifty thousand dollars to help finance this cooperative program. The companies were encouraged to make it possible for coal miners of exceptional ability to take a two-year curriculum (leading to a diploma) to qualify them for executive positions. A four-week summer course for miners wishing to become fire bosses, assistant mine foremen, and foremen, was also introduced, and about 200 men attended it altogether. In 1926 and 1927 a night lecture course for retail coal men was given, with a total attendance for the two years of 125.

Thomas S. Baker had succeeded A. A. Hamerschlag as president of the Institute in 1923, and by 1928, when Steidle left to become dean at Penn State, Baker's interest apparently had turned to a series of International Conferences on Bituminous Coal, the first of which he called in 1929. The summer work had already been discontinued in the mid-twenties, the two-year course and other cooperative activities were gradually dropped, and the four-year mining curriculum, from which about 75 men had graduated, was finally discontinued in 1936. Charles R. Fettke, professor of geology and mineralogy, remained at the Institute after mining instruction was dropped. A coal-research laboratory, of which H. H. Lowry is director, which was established in 1931, continues to do excellent fundamental research in that field.

In the metallurgical department, Crabtree, assisted by F. F. McIntosh, assistant professor of metallurgy, built up the work along advanced technical lines, and in 1923 a Metallurgical Advisory Board was organized to raise funds for and cooperate in advanced study and research in the metallurgical field. After 1926 it participated in the work on the physical chemistry of steelmaking, which the U. S. Bureau of Mines had initiated in its Pittsburgh laboratories. Over thirty research fellowships were carried at the Institute as a result of this Board's work, and many valuable bulletins were published. A Bureau of Metallurgical Research was organized during 1934 within the Institute to conduct advanced research in the field of physical metallurgy. This carried on work and issued publications on a variety of subjects, notably the preparation of pure metals and alloys, the crystal structure of solid solutions, intermetallic compounds, orientation relationships, internal strains, diffusion, rate of reaction in solid alloys, mechanical properties of single crystals and commercial alloys, oxidation, properties of commercial tin alloys, and the physical chemistry of metallurgical reactions. The laboratory has published 132 papers in these fields, and is one of the prolific sources of new data on physical metallurgy. F. M. Walters, Jr., was director of the Bureau until 1932, with James B. Friauf and V. N. Krivobok as assistants. R. F. Mehl (B.S. Franklin and Marshall, 1919; Ph.D. Princeton, 1924), then assistant director of research for the American Rolling Mills Co., was made director of this Bureau in 1932.

Professor Crabtree died in 1925 and Professor McIntosh left the following year. James Aston then became head of the Department of Metallurgy and remained until 1935, when Mehl became head of the Department as well as of the Bureau, which was renamed the Metals Research Laboratory of the

Institute. The Metallurgical Advisory Board went out of existence the same year. The College of Engineering of the Institute now offers four-year curricula leading to the B.S. degree in civil, mechanical, electrical, chemical, and commercial as well as metallurgical engineering. The B.S. degree can be obtained also by majoring in mathematics, physics, chemistry, general science, printing, and industrial education, the two latter being the vestigial remains of the former College of Industries. Both evening and day courses are given, the evening curricula requiring nine years to lead to a degree. Evening work in vocational fields over shorter periods leads to a certificate. Advanced work leading to the master's and doctor's degrees attracts greater student interest, however. Both in number of students and staff this is most probably the largest metallurgical department in the United States.

It is quite clear that when Andrew Carnegie founded the Technical Schools he had principally in mind vocational education of the higher sort, but he seems to have misjudged the actual requirements of the time in the region where he established the schools. The mining work sought to develop along the lines intended by the founder, at the same time carrying on normal technical instruction, and promoting research work, but was finally dropped. The metallurgical work prospered and expanded, perhaps because it concentrated more distinctly on research and high-grade technical instruction leading to a degree. The relative intensity of interest in advanced work and research in mining and metallurgy was probably also significant. Whatever the precise explanation, the development of mineral industry education at Carnegie Institute of Technology seems a convincing example of the points made elsewhere, that the organization of educational work, and the environment in which it is done, have a profound and often controlling influence on its success.

University of Illinois

Though the mining curriculum was dropped from the University of Illinois catalogues in the early nineties, interest there was rapidly increasing in other branches of engineering instruction. After Edmund J. James became president, engineering enrollment so increased that there were over 900 students in the College of Engineering in 1909–10. A fuel conference held at the University, March 11–13, 1909, under the joint auspices of the Technologic Branch of the U. S. Geological Survey, the State Geological Survey, and the University brought about a revival of mineral industry instruction. H. H. Stoek (E.M. Lehigh, 1888) who as editor of *Mines and Minerals* had participated in the mining work of the International Correspondence Schools (see pp. 259–260), and had written, revised, or edited many of its mining instruction pamphlets, was called to Urbana in October 1909 to become head of the mining department. He had naturally been impressed by the phenomenal growth of the I.C.S. correspondence work in the mining field, and proceeded to organize, in 1913, the Illinois Miner's and Mechanic's Institute. This provided a two-year extension course, offered at mining centers, to enable untrained men to prepare themselves to take State examinations for certificates of competency as mine foremen, inspectors, and hoisting engineers. Short courses of two and six weeks each given at the University, unit courses given in mining districts, organization of evening classes for miners, local miners' institutes, and a Questions and Answers office were features of this, which R. Y. Williams (E.M. Columbia, 1904) directed.

Great success was attained in this work during 1914 and the first half of 1915, but it was brought to an untimely end when the Governor vetoed the bill containing the appropriation for it, at the request of John H. Walker, president of the Illinois Federation of Labor. Walker published his letter in the *United Mine Workers Journal*, July 15, 1915. It is too long to quote here, but it requested the Governor to veto the bill unless the work was "put on an open, square, honest basis" and indicated that such a basis required that the field workers should be "miners satisfactory to the miners' organization of Illinois." President James of the University had flatly refused to appoint anyone except persons qualified by education and experience for such work, and organized labor preferred to see the work (which Walker admitted "is needed badly in our state") brought to an end rather than to permit it to continue outside its control. The other work of the mining department continued, however, and between 1912 and 1917 a first-class mining laboratory was developed, placing emphasis on coal mining and preparation. E. A. Holbrook has said of Stoek that "To him, more than any other man of his generation, belongs the honor of changing coal mining from a rule of thumb trade to an engineering science."

Among the men associated with Stoek in this work were F. C. Lincoln (Ph.D. Columbia, 1911), 1911–13; S. O. Andros, 1911–15; L. E. Young, 1913–14; E. A. Holbrook, 1913–17; A. C. Callen, 1914–17; C. M. Young, 1916–19; R. W. Arms, 1917–22; J. Burns Read, 1919–20; J. R. Fleming, 1919–21; A. E. Drucker, 1921–26; A. J. Hoskin, 1921–24; and C. M. Smith, 1921–37. After Stoek died, March 1, 1923, A. C. Callen was brought back from West Virginia University, where he had meanwhile been head of the mining department. I. M. Marshall was assistant professor of mining 1924–28; David R. Mitchell was appointed instructor in 1927, but left to become professor of mining at Penn State in 1937; H. P. Nicholson, now assistant professor, was appointed instructor in 1928. Under Callen's direction the academic work was greatly broadened and the department now offers four-year curricula leading to the B.S. degree in mining engineering (with options in coal mining, ore mining, mining geology, and mining administration), and in metallurgical engineering. Metallurgical instruction has been steadily strengthened in recent years. Ceramic engineering is offered in a separate department of the Engineering College. Illinois has been one of the outstanding schools in the development of ceramic engineering education, as is more particularly set forth in chapter 14.

University of Wyoming

Not all the attempts to establish mineral industry instruction during this period were equally successful. In some cases, as in the parable of the sower, the seed fell on stony ground. At the University of Wyoming (founded in 1886), Wilbur C. Knight, the professor of geology, who had had some operating experience at small mines, began to offer courses in mining before 1893 and finally secured the appointment of Charles H. Fulton (E.M. Columbia, 1897) as instructor in mining and metallurgy in 1899. Fulton left in 1900 to go to the South Dakota School of Mines, and was succeeded by James F. McClelland (E.M. Columbia, 1900), but he went to a dredging company in California the succeeding year. The author became instructor in mining and metallurgy in 1902, and, on the death of Professor Knight, the following year, was put in charge of all the instruction in mineralogy, geology, mining, and metallurgy, as well as the State assay work. This was not as difficult as it sounds, for, except for a coeducational class in general geology, only a few students were involved. At that time a considerable fraction of the total attendance at the University of Wyoming were preparatory students. This illustrates the general truth that a major handicap of western institutions was usually the lack of a sufficiently large body of well-prepared students, since the faculty had on it at the time such able and well-known men as Edwin E. Slosson and Aven Nelson. When the author returned to Columbia for graduate study in 1904–5, he was succeeded by others who were never able to put the mining and metallurgical instruction, as distinct from geology, on a firmly established basis, and it was finally dropped when J. R. Guiteras (E.M. Columbia, 1911) resigned in 1933, although the curriculum in petroleum technology he had established is still retained. At the time Knight tried to establish mining instruction at the University of Wyoming there was considerable interest in copper mining in the Encampment district, and elsewhere in the state, but it soon subsided. Coal and petroleum proved to be the only important mineral products of the state, and there was not enough student interest in general mining and metallurgical instruction to justify its continuance.

Cornell Engineering School

In the East, at Cornell, which had long had flourishing curricula in civil and mechanical engineering,* E. J. McCaustland, instructor in civil engineering, had begun giving an elective six-hour course in mining engineering previous to 1902. In 1903 he was made assistant professor of mining engineering and surveying, and the faculty the next year drew up a four-year curriculum leading to the degree of Engineer of Mines, which it submitted to the Board of Trustees for approval. The Board expressed general approval but deferred action. During 1905–6 and 1906–7 Professor

* The original plans of A. D. White, its first president, included mining engineering instruction.

McCaustland gave courses of three hours each on principles of mining, ventilation of mines and coal and metal mining, milling and ore dressing, and hydraulic mining and dredging, and a nine-hour course on design of mine plant. When he left to take a professorship in the University of Alabama in 1907 his place was not filled, and no mining instruction was thereafter offered. What might have happened if the Trustees had authorized the granting of the E.M. degree in 1904 is impossible to guess.

Colorado College

At Colorado College, a denominational college established by the Congregational Church at Colorado Springs, which, like most such institutions, largely consisted at first of a preparatory department, the collegiate work had so developed by the early 1900's that the authorities decided they would attempt to establish engineering instruction in order to meet the competition offered by other institutions in the state. Among the professors of engineering appointed under this plan was Fred Crabtree, who was professor of mining and metallurgy there from 1904 until 1906. He went to Jones & Laughlin in 1906 and the author was appointed to succeed him. Unable to report for duty before Jan. 1, 1907, the writer taught mining and metallurgy for the remainder of that academic year to two students, but left in the autumn of 1907 to go to Pei Yang University, China. Clyde T. Griswold (E.M. Columbia, 1905) next took over the mining instruction, but left in 1911 to go to Carnegie Institute of Technology. No further appointments in mining and metallurgy were made, the authorities having decided that it was unwise to attempt to maintain mining instruction at an institution so near the Colorado School of Mines.

Armour Institute

The Armour Institute of Technology had "a department of Mining and Metallurgy under the charge of Prof. Herman Haupt, Jr." according to the "Mineral Industry" for 1893 (p. 812). The "course of study" which follows this statement sounds like an ordinary four-year curriculum leading to the B.S. degree, but no other details are given, nor any information as to when it was dropped. Armour Institute, which was consolidated with Lewis Institute in September 1940 to form the Illinois Institute of Technology, has for some time offered instruction in metallurgy, but no curriculum leading to a degree in that subject. Plans have recently been made for the erection of a large metallurgical building, with the expectation of offering such a curriculum in 1942–43.

Northwestern University

At Northwestern University, U. S. Grant, head of the department of geology, was keenly interested in the lead-zinc ores of the Mississippi Valley. Some equipment was obtained and courses in mining and metallurgy were offered after 1907 by the geology department. Henry M. Parks was assistant professor of mining and metallurgy in 1906–7, but left the next year for Oregon, where he became dean of the School of Mines. These subjects never elicited enough student interest to justify establishment of a separate department or definite curricula in mining or metallurgy, though some courses are still listed in the catalogues as being offered every other year by the geology department.

Adequate Facilities

The widespread activity, successful and unsuccessful, in the development of education for the mineral industries during the closing years of the nineteenth century and the first years of the twentieth, was most visibly evidenced in the construction of mining-school buildings, especially those which were the gifts of private donors. This was the more remarkable because of the suddenness of its initiation, and its almost equally abrupt termination. As late as 1891–97, while Columbia was in the process of planning for and carrying out its move from 49th St. to the new site on Morningside Heights, effective efforts were made to secure gifts to provide the necessary new buildings. These met with considerable success and a large library, a chemistry building, a natural science building and a physics building were thus provided, but, in spite of the fact that its School of Mines had been one of the most important factors in the development of Columbia from a small college to a rapidly growing university, no money was forthcoming for a mines building, and all the engineering departments were crowded into a single building provided out of general funds.

A decade thereafter the national scene had completely changed. The announcement in 1903 by John Hays Hammond that he would give a mining and metallurgical laboratory building to his alma mater, Yale, only briefly preceded Simon Guggenheim's campaign for election as senator from Colorado and his offer to give a building to the Colorado School of Mines. Adolph Lewisohn's intention to give a School of Mines building to Columbia was announced in June 1904. Mrs. Hearst had been interested in the building program of the University of California for a decade before the College of Mining building, which she gave as a memorial to her husband, was dedicated in 1907. Mrs. John W. Mackay and her son Clarence announced their intention to give the University of Nevada a School of Mines building in 1906, and John D. Rockefeller provided the funds for a mines building at Case School of Applied Science the same year.

Such private donations stopped as abruptly as they had begun, and until John Markle made provision for a mining and metallurgical building and the support of mineral industry instruction at Lafayette, after 1920, there was no other considerable gift from private funds in this field. All the buildings described in chapter 13, with the sole exception of the building given to the University of Arizona in 1940 by the Phelps Dodge Corporation as a memorial to James Douglas, have been provided by public funds. In spite of the fact that the private fortunes that have been used to create foundations for a great variety of worthy objectives have chiefly been derived from mineral industry, no considerable private gift has ever been given for the *support* of mineral industry education and research. The buildings referred to above have, in some cases at least, chiefly imposed on the institutions to which they were given a necessity for securing continuing income to maintain a staff to utilize these physical resources. This, in turn, leads to emphasis on undergraduate work, which attracts a greater number of students, and is less expensive to maintain, than graduate work. Advanced study, the peculiar province of institutions of higher learning, thus tends to be neglected, unless it can be closely correlated with current commercial problems.

CHAPTER 10

YEARS OF CHANGE

THE preceding chapter has recorded the initiation of mineral industry education during the period 1890–1910 in numerous institutions that had not previously offered it. It should also be emphasized that in many institutions where instruction had begun before 1890, as recorded in earlier chapters, but had not yet become firmly established, this period was one of marked growth and development. This was not universally true, however, for at the Universities of Pennsylvania, Michigan, Illinois, Wisconsin, Washington (St. Louis), Iowa, Vanderbilt and Tennessee, and at the Polytechnic College of Pennsylvania, mineral industry instruction was being dropped during this period, instead of gaining in strength. It is necessary to emphasize this, because writers on the subject have not infrequently attempted to make a much too simple correlation between mineral discovery or production and the intensity of student interest in mineral industry curricula.

It would naturally be true that periods of large mineral production would, in general, coincide with cycles of business prosperity, and the latter are conducive to starting new ventures, educational as well as business. It should be equally evident that opportunities for business and professional success might, in such periods, appear to increase at a more rapid rate in industries other than mineral, or in the utilization of minerals rather than in their production. The author has not been able to perceive any simple and clear relation between interest in mineral industry education and mineral discovery, production, and utilization, or general business prosperity. On the contrary, the more the problem is studied the more complex the factors involved in it appear to be. In a later chapter an attempt will be made to analyze them in more detail.

Massachusetts Institute of Technology

Developments at two eastern institutions during that period were not covered in the preceding chapter and their history must be brought up to date to complete the picture before the discussion of the period after 1910 is begun. The first of these is Massachusetts Institute of Technology, where in 1892 a marked increase developed in interest in the mining and metallurgical curriculum, the number of degrees given by it in 1896 being double the average of the preceding period. It doubled again in 1900, and the number granted in 1906 was more than seven times the average previous to 1895, over 13 per cent of all the bachelor of science degrees awarded that year. There was no corresponding increase in the other curricula, which showed only a normal slow growth, and the conclusion seems inescapable that there was some reason, peculiar to the mineral industry, for the result. What it may have been is difficult to determine. The increase began before the gold discoveries at Cripple Creek and in the Klondike, and before the discussion in the A.I.M.E. Transactions of opportunities in the mining field. Possibly it was due to a great increase of interest in copper mining in New England, of which the flowering is pictured in Thomas W. Lawson's "Frenzied Finance," published in 1902. New England was also interested in iron and coal in Nova Scotia and in South African gold, and most of the students came from New England. This again illustrates the difficulty of establishing any clear relation between student interest in mineral industry curricula and events either within or outside any given institution. Between 1889 and 1893 mineral industry instruction at M.I.T. was given under four options; mining-mechanical engineering, mining-civil engineering, metallurgy-mechanical, and metallurgy-chemical. In the latter year these were replaced by single mining and metallurgy options in course III, and in 1904 a geological option was added. In the four-year period 1903–6, M.I.T. gave 123 degrees in mining and metallurgy.

In 1914 Professor Richards, who had been on the teaching staff for 49 years, and had been head of the mining and metallurgy department since 1873, retired and was succeeded by Dr. H. O. Hofman as department head, while Charles E. Locke

(S.B., '96), professor of mining engineering and ore dressing, who had been associated with Richards* since 1897, carried on the work in those fields. Dr. Hofman had been on the staff since 1889 and professor of metallurgy since 1898. His health was not good, and he was forced by it to retire as head of the department in 1920 and from his professorship in 1922. Carle R. Hayward (S.B. '04), who joined the department in 1907, carried on the instruction in process metallurgy thereafter. Meanwhile important developments, affecting the Institute as a whole, had taken place and must be briefly described.

The total registration at M.I.T. was 222 students in 1870–71, 937 in 1890–91 and 1900 in 1915–16. This steady growth had taken place on its original site (see p. 62) in downtown Boston, where naturally it led to great overcrowding. It was proposed to move to a new site on the Charles River, in Cambridge, near Harvard, and as a result of this a treaty of alliance with Harvard was negotiated under which Harvard was to transfer all its engineering instruction to M.I.T. This, entered into in 1915, involved a readjustment of the curriculum in course XII, geology, to provide for the continuance of the Harvard mineral industry instruction. The new buildings at Cambridge were completed and occupied by M.I.T. in January 1917, but so much opposition had developed (see p. 143) among Harvard alumni to the transfer of its engineering work to M.I.T. that the alliance was abrogated in 1918.

Course XII, geology, was restored to its original form in 1919 and in 1920 Dr. Waldemar Lindgren, who had been head of the geology department since Jaggar left in 1912, became administrative head of the mining and metallurgy department as well when Professor Hofman was obliged to give up his administrative duties. Dr. George B. Waterhouse (Ph.D. Columbia, 1907) became professor of metallurgy in 1922 and W. Spencer Hutchinson (S.B. 1892) became professor of mining in the same year and head of the department of mining and metallurgy in 1927. At that time course III was again divided into four options—mining, petroleum production, production metallurgy, and physical metallurgy—and Dr. R. S. Williams (S.B. '02) was transferred to the mining and metallurgy department as professor of physical metallurgy, taking with him the work in metallography which he had developed in the chemistry department. Instruction in geophysical prospecting was initiated in 1928; in 1930 heat-treatment of metals was transferred from the mechanical engineering department and X-ray studies from the physics department to mining and metallurgy; ceramics was similarly transferred from the physics department in 1933. In 1937 metallurgy was separated from mining to form a department with Professor Williams as its head, and it was announced that the mining and petroleum-production options in course III would be discontinued after 1940. The reason for this apparently was that 10 S.B. degrees were given altogether in course III in 1936, the same number as had been given in 1918, though the total enrollment of the Institute had meanwhile increased from 1700 to 2500 and the total degrees given from 324 to 410. In metallurgy 10 S.B. degrees were given in 1938 and 19 in 1939. In addition, five M.S. degrees and four Sc. D. degrees were given in metallurgy in 1939. Prior to 1922 master's and doctor's degrees were given only in mining and metallurgy, after that they were separate. The bachelor's degree in mining is now no longer offered in the New England area though M.I.T. still offers some mining courses in its geology department.

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* Professor Richards was presented with the gold medal of the Mining and Metallurgical Society of America for advancement in the art of ore dressing. The tributes paid him at that time can be found in the Society's *Proceedings*, vol. 8, 1915.

Columbia School of Mines

Columbia School of Mines was left, in chapter 8, with its name having been changed, in 1896, to Schools of Mines, Engineering, Chemistry and Architecture, to more clearly express the fact that it had for 30 years been offering a variety of curricula leading to degrees in other subjects than mining and metallurgy. All these schools were under a single faculty, now known as the Faculty of Applied Science. It was still at the original site, bounded by 49th and 50th Streets and Madison and Park Avenues, where it had been founded in 1864. This had always been considered only a temporary site for Columbia, and many others had been considered. Increased attendance, especially on the civil and electrical engineering and architecture curricula, put such a strain on facilities there that in 1892 the Trustees secured an option on the four blocks lying between 116th and 120th Sts. and Broadway and Amsterdam Avenue and proceeded to raise the money to erect buildings on it. These were sufficiently completed by the autumn of 1897 so that classes could be transferred there. A large chemistry building provided space on its top floor for architecture and in its basement for metallurgy; geology was housed in a corresponding natural science building; and mining, civil, and electrical engineering jointly occupied an engineering building.

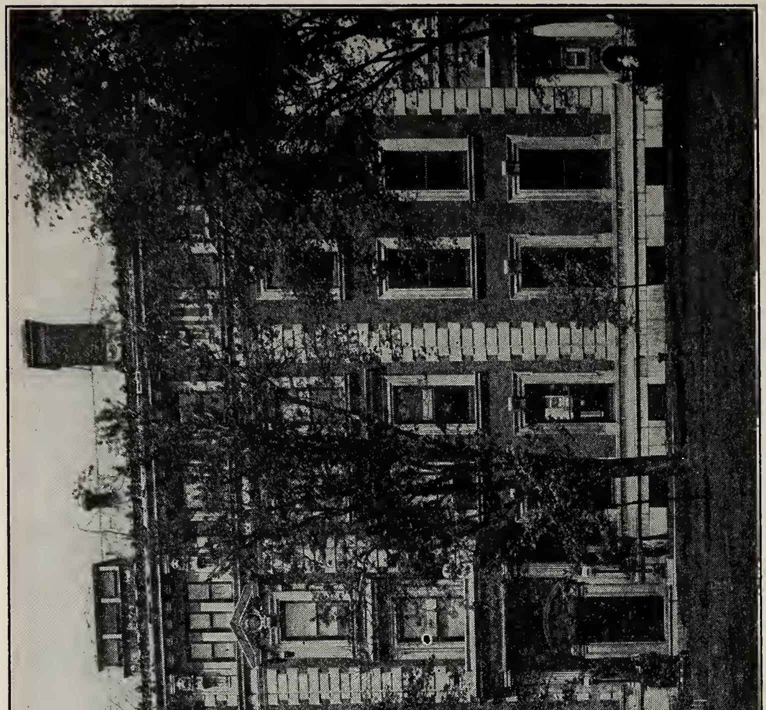
The better facilities thus provided must have seemed commodious at first, but quickly became crowded, since still another curriculum, mechanical engineering, had been established, while enrollment in all the others, especially mining, increased. In 1894–95 there were 54 mining and metallurgical students out of a total enrollment of 374, and 123 in 1900–1901 out of 566. The proportion of mineral industry students had therefore increased, though still only a little over 20 per cent of the total. Professor Egleston, who had been professor of mineralogy and metallurgy since he founded the School in 1864, retired in 1897, and the chair was divided. Henry M. Howe was appointed professor of metallurgy, and Alfred J. Moses (E.M. 1882, Ph.D. 1890), who had been adjunct professor of mineralogy, was made full professor of that subject. It will be remembered that Howe had graduated from M.I.T. in 1871, had first worked in the metallurgy of copper and then turned to the metallurgy of iron and steel, his "Metallurgy of Steel," published in 1890, having brought him world-wide fame. At the time of his appointment he had a consulting office in Boston and was also lecturing at M.I.T. At the old site of Columbia, the work in metallurgy was virtually without laboratory equipment, but adequate provision was made for it in the new quarters on Morningside. A new metallurgical curriculum was devised and the metallurgical instruction in the mining curriculum was strengthened. It would be natural to suppose that this was the main reason for the increase in the number of students in mineral industry, but this was not true, for there was no marked increase in the undergraduate enrollment in the metallurgical curriculum, though there was some increase through graduate students in that subject coming to work under

Howe, among them John Mathews, William Campbell and George B. Waterhouse.

In 1902 the Trustees took the department of architecture out of the Faculty of Applied Science, and set it apart as the nucleus of a future School of Fine Arts. What had been the School of Mines was thereafter known as the Schools of Mines, Chemistry, and Engineering. A Faculty of Pure Science had been organized in 1892, and several of the departments originally only in the School of Mines, such as geology, chemistry and physics, had for a decade been in both these faculties.

In 1904 it was announced that Adolph Lewisohn, president of the United Metals Selling Co., would give Columbia a School of Mines building, to house the departments of mining and metallurgy. A six-story building, 57 by 145 ft. in area, and identical, except for details of architectural treatment, with the earlier engineering building, was constructed and equipped. Some of the metallurgical and assay equipment was moved from the chemistry building and some new and improved types were provided. The two lower floors, which had windows only on the Broadway side because of the higher elevation of the inner campus, were chiefly given over to ore-dressing equipment, of which very little had been previously available. The period was one in which great importance was being attached to full-scale operating equipment for laboratories, experience not yet having demonstrated the difficulties involved in the laboratory use of large machines, and it is cause for congratulation that relatively little of such bulky equipment was provided in the original plans.

In 1905 Columbia granted 47 Engineer of Mines degrees; the largest number in its entire history, and a great increase over 1899, when it had granted seven. The number in 1906 was almost as large (45), followed by a decrease to 31 in 1907 and to 29 in 1909. In 1910 there were 46, with an equally sharp drop to 25 in 1913, a recovery to 38 in 1912, and another decline, to 11 (the lowest since 1899), in 1916. There is no plausible explanation for these observed differences between consecutive years, but the general trends are evident; large numbers graduated between 1875 and 1888, an average of 21 yearly. The period 1890–99 showed an average of only half the earlier period



School of Mines Building, Columbia University. Erected 1906.

(though there were 17 in 1898) while the average for 1904–13 was 37, or more than three times the intervening period.* I do not know the reason for this; it does not seem plausible that schools developing in the West were attracting students who might otherwise have gone to Columbia, for that would be inconsistent with the renewed growth after 1900. Probably the causes were complex.

In 1906–7 still another curriculum was introduced, four years leading to the degree of Chemical Engineer. This proved attractive, enrollment in it increased rapidly, and in 1917 more degrees were awarded in this curriculum than in any other. The department of chemistry had grown enormously, having awarded many master's and doctor's degrees in that subject, and in 1915 it was divided into two—a department of chemical engineering, which gave the instruction in that subject and in industrial chemistry, and a department of chemistry, which concentrated upon the pure science aspects of that subject—but it was still regarded as a part of the Schools of Mines, Engineering, and Chemistry.

Meanwhile an extremely important development was taking place. The period was one of even more rapid growth of Columbia as a whole; its total student body in 1900–11 was 8000 as compared with 2000 in 1896–97. Most of this growth was in fields for which only libraries and classrooms are required, as compared with the increasingly large and expensive laboratories needed for science and engineering instruction. There is no record that the authorities took cognizance of this economic factor, but they did initiate studies of their problems. An increase of the tuition fee from $200 to $250 per year† in 1904–5 had had no perceptible effect on checking the increase in enrollment. Studies were made of the proportion of the students admitted to the freshman class who eventually took a degree. Before 1901 it had averaged around 20 per cent, with slight but not very significant differences between curricula. Of the students admitted in 1904 who took a degree in 1908 the percentage ranged from

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* The total registration in all the Schools under the Faculty of Applied Science increased from 397 in 1896–97 to 718 in 1908–9. The mining students increased more than the average.

† Then the highest in the United States.

22 to 48, according to curricula, mining being the lowest. Without attaching too much significance to comparative figures for a single year, it was seen that some improvement had been made in restricting admissions to students more likely to complete their curricula, thus easing the burden of providing plant facilities. It was desired to make further advance along this line.

When Columbia School of Mines was first founded, it was the custom to speak of its student body as "graduate," as compared to the undergraduate students of the College. When the curricula were increased from three to four years in length, in 1868, the first year was called a "preparatory" year, though its intellectual content was quite as advanced and heavier than the first year of the College curriculum. The engineering degrees awarded by the School of Mines were always thought of as being the equivalent of masters' degrees, many of the men who took the Engineer of Mines degree had already taken a bachelor's degree from some college, and since they usually had to spend at least two years in qualifying for the E.M. it was for them at least the equivalent of a master's degree. Since 1896 it had been possible for a student to enter Columbia College, transfer to the School of Mines after two years in the College, and receive the A.B. degree at the end of four years and the Engineer degree in six.

In his report for 1910, President Butler discussed the relation of the School of Mines, Engineering, and Chemistry to the rest of the University at considerable length, concluding with five recommendations, of which one was that students thereafter should not be admitted to that School except after completing two years in Columbia College or some other institution of equal standards. The general idea was that during those two years they should complete most of the work of the first two years of the engineering curricula, and that the first two years after being admitted to the engineering school should be devoted to unspecialized study of engineering and lead to the award of the B.S. degree without designation of field. After two more years of specialized study, the appropriate engineering degree would be attained, thus clearly making it at least equal to a master's degree. In February 1911, the Committee on Instruction of the Faculty began a study of these recommendations. Their report was adopted by the Faculty in April, submitted to the Trustees, studied by their Committee on Education and finally approved in January 1912.

The plan in its final form differed somewhat from the first proposals. Instead of two uniform years in the College and two uniform years in the School of Mines, Engineering and Chemistry leading to an undesignated B.S. degree, it provided for three uniform years in the College, and immediate beginning for specialization on entering engineering, attaining the engineering degree after three more years there. After one year in the engineering school the student might receive the A.B. degree, and after two years the B.S. degree, with designation of field. This is the plan that was put into effect with the class that entered in the autumn of 1914; the last four-year engineering degrees were given in June 1917, among them 22 mining engineers and three metallurgical engineers. Theoretically none would have been given in 1918 and 1919, and the first six-year engineering degrees would have been awarded in June 1920. Actually nine E.M. and one Met.E. degree were awarded in 1918 and two E.M. degrees in 1919, to students who either had not completed their work in normal time or had been admitted to advanced standing.

What the result of the introduction of this plan would have been under normal circumstances can never be determined, for the United States entered the World War in April 1917 and by autumn the University was deeply involved in war work. The engineering professors were either conducting war schools on the campus or were engaged in similar work elsewhere. The students who had entered in 1914, 1915, and 1916 were equally occupied, usually in something other than their regular work. It was not until the autumn of 1919 that the School was back on a normal basis, and the students who entered in 1914 and should have received engineering degrees in 1920 did not actually attain them until 1921.

The total registration in the Schools, which had been 724 in 1910–11, was 166 in 1919–20 and 191 in 1920–21, the latter including six students in a newly established curriculum in industrial engineering. The differential effects upon the curricula was striking, as is shown by the accompanying table of total registrations in curricula (next page).

Comparative Registrations, Columbia

Curricula	1910–11	1920–21
Mining Engineering	171	18
Civil Engineering	134	9
Mechanical Engineering	97	36
Electrical Engineering	56	44
Chemical Engineering	47	64
Metallurgical Engineering	15	14
Industrial Engineering		6

These figures represent for 1910–11 the second, third, and fourth years of four-year curricula, as compared to three-year curricula based on three years of pre-engineering work in 1920–21. Apparently the new system had not visibly affected chemical or metallurgical engineering, had curtailed electrical engineering less than mechanical engineering, but had disastrously affected civil and mining engineering.

The students who would, under the previous system, have entered the uniform first year of the Schools of Mines, Engineering, and Chemistry were now being admitted to the first year of Columbia College and required to remain there three years before being admitted to these schools. The number of students admitted to the first year of the College was 400 in 1910–11 and in 1920–21 it was 613, which on the face of the figures would seem to provide about the same number of pre-engineers as had previously entered a uniform year. Actually that was not the case, because the College is also preparatory to law, journalism, and medicine, and out of those College freshmen who actually were preparing to enter the engineering curricula a smaller proportion survived after three years. The uniform first-year engineering class in 1909–10 had 223 students in it, the second-year class the following year had 213. The registrar's figures do not show how many of the latter had been admitted to advanced standing, but it must have been a considerable number to produce a second-year class almost as large as the freshman class.

The registrar's figures for this period also do not show the number of students who, after having spent three years in pre-engineering work in the College, entered the Schools of Mines, Engineering, and Chemistry, but later figures indicate that it was approximately only one-half as many as had constituted a normal pre-1914 second-year class in those schools. The number admitted to advanced standing in those schools decreased even more, because the required three-year pre-engineering curriculum in the College was so devised that it now differed markedly from the ordinary college curriculum. The result was that even those students who had completed four years of work at some other college might find, on transferring to Columbia, that not only would they not be credited with one year toward completion of the engineering curricula, but that it might be necessary to spend one year in Columbia College making up subjects required in its pre-engineering curriculum which had not been included in their own college work. In this way they would spend eight years, not six, in attaining a Columbia engineering degree.

The result of this was that the number of students admitted yearly to advanced standing in the Schools of Mines, Engineering, and Chemistry was markedly reduced. Here again the principal effect was upon the mining curriculum. Seven of the 14 men to whom E.M. degrees were awarded in 1901 had been admitted to advanced standing, while only two of the nine men to whom E.M. and Met.E. degrees were awarded in 1921 were so admitted; one of them was a European student and the other had taken his E.M. degree from a western institution in 1917. These forces, plus the fact that registration in the mining curriculum had been declining in the three years preceding the going into effect of the new system, produced the almost inevitable result that never again did registration in the mining curriculum at Columbia attain the high levels of 1901–11. The number of degrees granted yearly after 1921 remained at about the level of 1890–95, but the registrations in the School were much smaller, because under the old system many students attended for a time, but did not take a degree; under the new one if a student was admitted he usually completed the work for the degree.

So much space has been devoted to this development at Columbia because a concise and accurate presentation of it is not elsewhere available, and it is extremely important "case" material for discussion that is to follow. But before that can be attempted it will be necessary to review briefly the various investigations of engineering education in general which had been made since the Society for the Promotion of Engineering Education had been founded in 1893, as recorded on a previous page. That society had been active, holding meetings, publishing an annual volume of proceedings and, after 1900, a monthly journal, but the mining and metallurgical educators had never been active in the society, and F. A. Thomson's "The Curriculum of the Mining School," published in its 1915 proceedings, was about the first time the mineral industry field received its attention. In 1907 the S.P.E.E. invited the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers and the American Chemical Society* to participate in the creation of a joint committee to make a study of all branches of engineering education. Only the Civil Engineers contributed any funds toward the study, and the Carnegie Foundation for the Advancement of Teaching was requested to take over the material collected by the committee and subject it to full-time study by a qualified person. Charles R. Mann, then associate professor of physics in the University of Chicago, was secured to make this study, and spent several years upon it. His broad approach to it is perhaps best indicated by the bibliography of eighteen titles appended to his report,[32] which ranged from Beard's "Economic Foundations of Jeffersonian Democracy" to Taylor's "Principles of Scientific Management."

The report, when finally issued in 1918, was of 130 pages, divided into three parts—an analysis of present conditions, statement of the problems of engineering education, and suggested solutions. An appendix of nine pages on objective tests was supplied by E. L. Thorndike. Twenty of the leading engineering schools were studied in some detail, but as only a few of them had been at all prominent as yet in the mineral industry education field it was natural that that phase of the subject received little attention in the report, which attracted wide attention because of its vigorous and forthright attitude on many matters, such as the lecture system of presentation and the number of credit-hours required for graduation.

Meanwhile the results of a study of the subject through questionnaires had been published, in 1916, but were not particularly revealing, since they showed that 1500 engineers thought personal qualities more important than knowledge of engineering science or operating techniques in determining probable success or failure in engineering; and 7000 engineers thought character much more important than knowledge and technique in judging the reasons for engineering success or sizing up young men for employment or promotion. The Mining and Metallurgical Society of America appointed a committee of three (one of them a professor of geology) to make a report to the Society on Technical Education. Its 32-page report, published on Sept. 30, 1921, divided the whole field of mining engineering into subheads and studied the curricula in mining engineering and metallurgy of 24 schools as to time distribution. It reached the conclusion that about one third of the time of an average curriculum is devoted to fundamental studies, one quarter each to general and specialized subjects in science or engineering, and less than one tenth of the time to cultural subjects, though there were wide differences between individual schools. Much of the report was devoted to an expression of views on the general subject of mining education.

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* The A.I.M.E. does not appear in the original list, but its representatives signed the final report.

In November 1920, President Butler appointed a committee of Trustees and the Committee on Education of the Faculty of Applied Science of Columbia to work on problems of the Schools of Mines, Engineering, and Chemistry. The general committee set up 12 subcommittees, which are described in detail in the Dean's report for 1920–21. They continued their work for several years and made a number of progress reports, but no final report. Before this committee completed its work the S.P.E.E. obtained a grant (1923) from the Carnegie Corporation to enable it to begin a five-year program of investigation of engineering education. William E. Wickenden, then assistant vice-president of the American Telegraph and Telephone Co. (now president of Case School of Applied Science) was secured to head the investigation, and during the subsequent years more than 20 reports and bulletins were published. Few of these dealt in any detailed way with mineral industry curricula;* *Bulletin* 13, Opinions of Professional Engineers Concerning Educational Policies and Practices, had a section on mineral technology, compiled from the replies of 177 engineers in that field who answered the questionnaire.

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* Six of them appeared in the latter half of 1926 and apparently were the cause of President Butler's appointment of an alumni committee "on the state of our engineering schools," which made a 24-page printed report to him in October 1927.

These engineers were asked to state whether they favored distinct curricula in the several branches of mineral industry education, a single inclusive curriculum, a single curriculum for three years followed by options in the fourth, or a single curriculum for most institutions, with one of the others for the rest. Nearly half the replies favored a basic curriculum for three years, followed by a fourth year of specialized work, about a quarter favored a single basic curriculum, one seventh a single basic curriculum for most schools, with options or distinct curricula in a few, and one eighth preferred completely distinct curricula in all branches. Since less than one fifth of the replies were from educators it may be doubted whether those answering all had exactly the same concept of what was meant by these different categories, but it is clear that the great majority believed that there is a central basic field of knowledge that should be contained in all mineral industry education, and that special education may be postponed until this has been acquired.

One may guess that the fraction expressing a preference for separate curricula were perhaps educators, who realized more clearly than others that specialization in a fourth year usually makes it necessary to rearrange the preceding years so as to lead up to the specialty. It would scarcely be possible, after three uniform years, to specialize during a fourth year in such diverse branches as petroleum geology and physical metallurgy. While this study was going on the actual trend was toward setting up more diverse curricula, as will be seen in the next chapter. The group options recommended were metallurgy, metal mining, coal mining, economic geology, mining geology, petroleum geology, petroleum technology, and ceramics, in the order of the relative number of times they were named.

The second topic covered in this study was the technical content of curricula. The replies were divided into those that should appear in all curricula, and those to appear in mining, metallurgy, economic geology, petroleum technology, and ceramics. Some of the results were puzzling; of those who replied, 75 per cent thought mineralogy should appear in all curricula but only 50 per cent said it should appear in the economic geology curriculum. Properties and preparation of ceramic materials should appear in all curricula, in the judgment of 7.5 per cent of those who replied. The report does not state whether the subject headings were given in the questionnaire, or whether those queried were asked to set down the subjects they thought should be included in the various curricula. It seems probable that there was considerable difference of opinion as to what would be actually taught under the specific headings listed and apparently mineral industry educators have not made much use of this survey in determining what subjects should be included in the curricula they have devised.

Summary of Period 1890–1910

Summarizing, the period 1890–1910 was one of great growth of student interest in mineral industry instruction, resulting in a corresponding increase in provision for giving it, in which most of the institutions rather blindly followed the courses set by Columbia and Massachusetts Institute of Technology, which were furnishing a majority of the teaching staffs. This led into a period of reexamination of engineering instruction in general, and some sweeping changes in the academic organization of leading institutions. The public demand seemed to be for unification and standardization of engineering instruction. Forces had long been at work, however, which eventually produced more, not less, diversification in mineral industry curricula, and succeeding chapters will consider them in detail.

Chapter 11

EDUCATION FOR THE PETROLEUM INDUSTRY

EDUCATION for the mineral industry was at first a single comprehensive curriculum, but it was early recognized that the main basis of mining is physics, while that of metallurgy is chemistry. The first school to offer curricula leading to degrees in mineral industry education in the United States (1853) had separate ones in mining and metallurgy. The Columbia School of Mines (the first really successful one) had only a single curriculum when it opened in 1864, but within a few years had so reorganized its work that it offered curricula in mining, metallurgy, geology, chemistry, and civil engineering. Interest in the metallurgy or geology curricula was slight at first, and for the next 30 years the great majority of Columbia students took the mining curriculum, probably partly because it contained nearly as much geology as the geology curriculum, practically all the metallurgy, and most of the chemistry, and partly because of the degree awarded for it. Other schools kept their mining curricula equally broad, and as late as 1900–1910 men were graduating as mining engineers who were practically as well prepared to make geology or metallurgy their life work as they were for mining.

Gradually, however, the subject matter of mining geology and metallurgy became so enriched through research and development that separate curricula in them became worth while; their progressive development is the subject of another chapter. Mining curricula also began to be somewhat diversified, and schools in areas where coal mining was of outstanding importance began to offer options in coal mining, the earlier curricula having been chiefly aimed at metal mining. The petroleum industry began its meteoric rise about the same time as mineral instruction in this country, but little more of applied science attended its birth than had attended such ancient practical arts as copper and iron smelting. The boring of deep wells for brine and water was so old a technique that books had been published on the subject in Europe, while for nearly two thousand years the Chinese had practiced it without writing much about it. When the first well in this country specifically intended to produce petroleum (many brine wells had previously produced it) was put down at Titusville in 1859 it was bored by an experienced brine-well driller, "Uncle Billy" Smith, and involved nothing novel except the idea that crude petroleum would come out of it instead of brine. The credit for that idea undoubtedly belongs to G. H. Bissell, instead of to the ex-railway conductor, E. C. Drake, whose vociferous claims, and the need in popular psychology to identify a discoverer, led to his being popularly considered the "founder" of the petroleum industry.

No one person can validly claim to be a founder of the petroleum industry (unless it were John D. Rockefeller for his business organization of it), since the refining of the crude is as important as its production. For that technique there was also an ancient background in the art of distillation, whose origin is lost in the dim mists of early time. More directly applicable was the distillation of bituminous substances to yield illuminating gas and, later, "coal oil," on which work had been started before the beginning of the nineteenth century. The point is that the initiation of the petroleum industry, as an industry, consisted in the application and combination of existing techniques rather than the development of any important new ones.

The problem of where to drill the wells was solved, in the beginning, by putting down the first one near where petroleum came to the surface, and moving outward till the boundaries of the pool had been passed. Geologists familiar with the flow of artesian waters would naturally have ideas about how petroleum occurred underground, and soon after the Titusville well came in H. D. Rogers, who had mapped anticlines in his Pennsylvania Geological Survey report, published in 1858, pointed out that one occurred along Oil Creek and attributed[26] the accumulation of the petroleum to the structure. T. Sterry Hunt pointed out as early as 1861 that the Canadian wells "occur along the line of a low, broad anticlinal axis," and E. B. Andrews, of Marietta College, expressed similar views. Andrews was retained as consulting geologist to an oil company[14] as early as 1864. Alexander Winchell, in 1865, pointed out the need of an impervious cover to retain gas and oil—a thesis which led J. D. Whitney astray, for his first report on the geology of California (1865) prophesied that southern California would not produce petroleum in important amounts because "the bituminous shales are everywhere turned up on edge and have no cover of impervious rock . . . "

In spite of these early observations on petroleum geology, practical working hypotheses covering the origin, distribution and natural storage conditions of natural gas and petroleum were not worked out until Edward Orton and Israel C. White developed them. White, who had also been a geologist on the Pennsylvania Survey, was retained by Pittsburgh businessmen in 1883 to find natural gas. He successfully applied these theories as to oil and gas accumulation and as an eventual result became the first geologist to make a specialty of the field of petroleum and gas, in which he was the outstanding man of his time. He was professor of geology at the University of West Virginia from 1877 to 1892 and State Geologist from 1897 until his death in 1928.

There was not at first, however, much need for applied petroleum geology, since all the crude required to supply the need for kerosene was easily obtained from rather shallow wells. Toward the end of the nineteenth century the automobile was rapidly developing; four motor cars were built in 1895, a thousand in 1898 and 11,235 in 1903. This foreshadowed a real market for the lighter fractions of crude petroleum, which until then, except for a limited use as solvents, had been disposed of by putting as much as regulations permitted into the kerosene, and burning, in open pits, the unsalable surplus. Crude production in the United States, which had taken from 1859 until 1891 to attain an annual output of fifty million barrels yearly, doubled in the next 12 years, and doubled again in 8 years; by 1912 it was five times what it had been in 1890.

Such a rapid growth in the production and refining of petroleum naturally stimulated the application of science to the problems of the industry. In California, where production had taken from 1876 to 1895 to reach a million barrels yearly, but doubled in the next three years, professional petroleum geologists began to be employed in 1897, "on the Gulf Coast about 1900, in Mexico in 1909, and in Oklahoma in 1913. Today there are about 5000 petroleum geologists in the United States, with probably 2000 more working in other countries."[26] No similar figures are available as to the employment of chemists in oil refining, but it seems probable that a similar correlation existed.

The schools had paid what seemed a due amount of attention to petroleum from their earliest days. At the University of Pennsylvania, J. Peter Lesley included petroleum in his treatment of economic geology in 1860–61. At Columbia School of Mines Vinton's instruction in mining discussed the drilling of artesian, brine, and oil wells, while Charles F. Chandler, its dean and professor of applied chemistry, devised the flash-point test for kerosene, and was the foremost chemical consultant of the petroleum industry of the time. Professor Newberry included petroleum in his treatment of economic geology. Similar practices were followed at the other schools as they developed their curricula, though the amount of attention varied at the different schools according to the experience and interests of the men doing the teaching. This general condition obtained until 1910, when the schools began to react to the rapidly developing need of the petroleum industry for trained men and more highly developed training.

University of Pittsburgh.—At the University of Pittsburgh, Roswell Hill Johnson was made assistant professor of oil and gas mining in 1912. Born at Buffalo in 1877, he had taken the B.S. degree at the University of Chicago in 1900, and an M.S. at the University of Wisconsin in 1903, working in the field of biology. Since his father and brother were oil and gas operators he took graduate work in geology at Columbia in 1908–9, and from then until he went to Pittsburgh, in 1911, he was a consulting geologist in Oklahoma. An oil and gas mining option in the regular mining curriculum was established and courses were offered in the production of oil and gas, geology of oil and gas, the examination of oil and gas properties, and a seminar and laboratory work in oil and gas. Several students took the curriculum the first year (1912–13) and their number steadily increased. In 1914 Johnson was made professor of geology and oil and gas production, and head of a separate department of oil and gas production

Lewis G. Huntley was appointed lecturer in the department and soon 18 separate courses in these subjects were being offered. The degrees of Geological Engineer and of Petroleum Engineer were conferred on graduates of the department.

Missouri School of Mines.—At Missouri School of Mines a young oil operator from Oklahoma, M. H. Valerius, presented himself in 1912, asking for a course in petroleum geology. Since none was offered, V. H. McNutt, a young geology instructor, was designated to give the instruction, with the result that he left the next year to establish himself as a consulting petroleum geologist in Tulsa, beginning a successful career which included the discovery of two oil fields and the potash deposits of New Mexico. The department at Rolla began to offer elective courses in petroleum geology in 1913, and one in petroleum-production methods in 1914.

University of California.—At the University of California the department of chemistry offered a course in petroleum refining as early as 1910, and Prof. E. B. Durham gave a course in oil-field practice to a few students in the mining department in 1913. In 1915 Prof. A. C. Lawson, then acting dean of the College of Mining, asked L. C. Uren to plan a four-year curriculum leading to a petroleum engineering degree. Professor Uren gave a course in drilling methods in the autumn of 1915, and one on production methods in the spring of 1916. From this there was gradually developed a special curriculum, though somewhat interrupted during the World War, in which 150 students are now enrolled.

University of West Virginia.—Though I. C. White became professor of geology in the University of West Virginia in 1877, and naturally gave especial attention to oil and gas geology, the time was not ripe yet for specialized instruction in that field, and apparently when he left in 1892 his successor did not have equal interest in the subject. It was not until 1915 that an oil and gas option was introduced into the mining curriculum there. The geology department gave a two-credit course in oil and gas production which, in addition to its regular geology courses, was the only difference between the new option and the regular mining curriculum. This relation continued until 1928.

Stanford University.—At Stanford University (see p. 148) geology and mining were a single department until 1918, and many graduates went into work in the petroleum industry without specialized preparation for it. In 1914 Valentin R. Garfias was secured to teach a single course in petroleum-production engineering. In 1918 the departments were separated and mineral industry instruction placed on the basis of two years of graduate work following an undergraduate curriculum containing the fundamentals of engineering as well as sciences and liberal arts. Carl Beal succeeded Garfias in 1918, and was followed by J. E. Elliott in 1920. Frederick G. Tickell, now the executive head of the Mining Department, took over the petroleum engineering instruction in 1921, and laboratories were equipped for testing fuels and oils, drainage mechanics, core analysis, and related subjects. Of the petroleum courses offered, two are given primarily to undergraduate students, and the remainder to graduates. The graduate curricula are not fixed, leaving the individual a wide range of choice. The field of petroleum refining has not been developed.

Massachusetts Institute of Technology.—Interest in petroleum at Massachusetts Institute of Technology became specific enough in 1915 for the geology department to offer a separate course in the economic geology of coal and petroleum. I. D. MacKenzie gave the instruction, with Ralph Arnold as special lecturer. This continued to be given and geology and mining were combined administratively into a single department, under the direction of Waldemar Lindgren, in 1921–22. Five years later the departments were again separated and in 1926 H. T. Mann (E.M. Rolla, '10, engineer Josey Oil Co., 1924–26, Sc.D.M.I.T., '25) was added to the staff of the mining department, where he offered three courses—one in the elements of petroleum production, a second on petroleum production and utilization, and a third in advanced petroleum engineering. In 1938 a fourth course, Outline of Petroleum Production, was added. At the same time it was decided to discontinue the mining department after 1940. Mann left in the autumn of 1939 to go to Rolla. The geology department continued to give its courses in geology of coal and petroleum, and in the economic geology of fuels, adding in 1930 an advanced course in the geology of petroleum. Engineering instruction for work in the petroleum industry has, however, been discontinued. This is the only institution that offered petroleum engineering instruction only to discontinue it later.

Post-war Developments

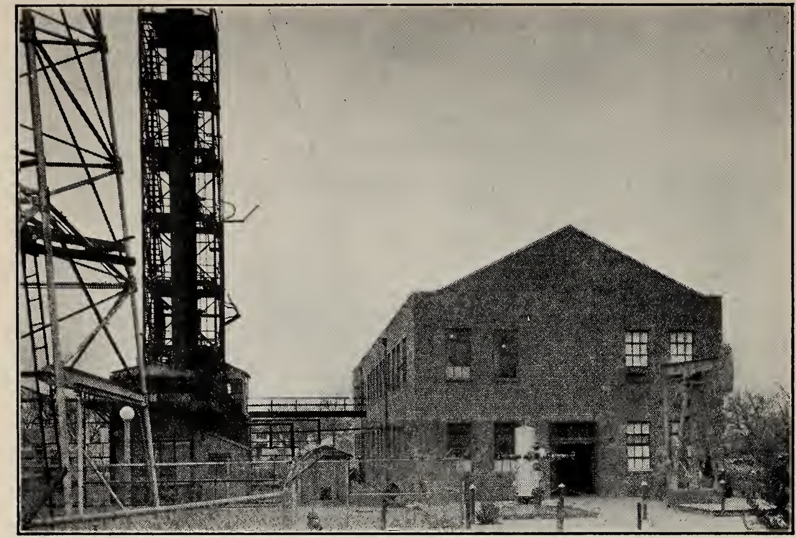
Colorado School of Mines.—At Colorado School of Mines the establishment of a separate petroleum engineering department dates from 1920. A course in the geology of oil and gas had been offered in 1916; this work was gradually increased and the mining department also increased its emphasis on the drilling of wells and the mining of oil shales and sands. W. W. Kirby was placed in charge of the new department, and at first there was no distinction between production and refining, the students being permitted to select from among various optional courses. In 1926 two optional curricula were offered, the one in petroleum-production engineering emphasizing geology and the engineering phases of the petroleum industry, while the refining option similarly emphasizes chemical and mechanical engineering. Subsequent changes are described in the *Mines Magazine*, April 1934.

An interesting feature of the production work is a six-weeks field course, in cooperation with the geology department, in which a petroleum structure in Wild Horse Park, northwest of Pueblo, is mapped, the geology studied, a well located and the last three weeks spent in drilling with cable tools to the Dakota sand. The first petroleum engineering degree was awarded in 1922, and 23 were awarded in 1932. The present head of the department, C. F. Barb, took his degree in 1925.

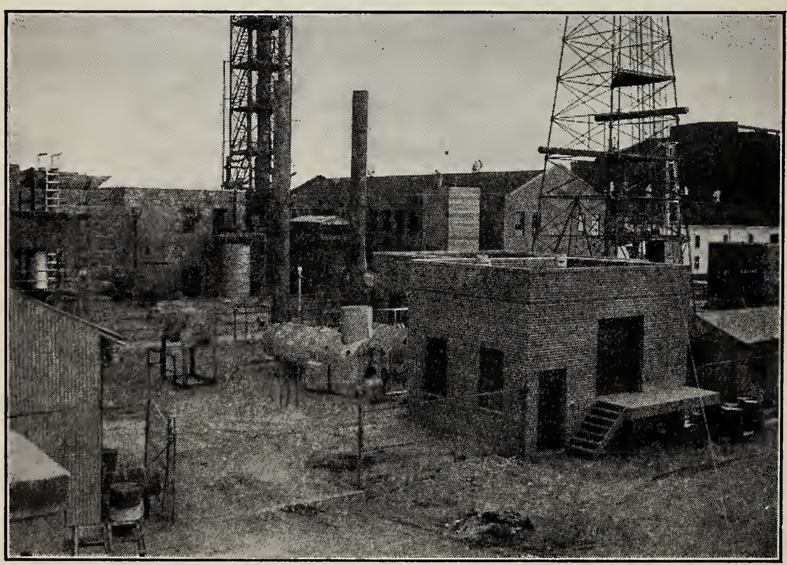
Missouri School of Mines.—The World War of 1917–18 had seriously affected the mineral instruction of all the schools of the country, and it was not until 1919–20 that most of them began to return to a normal basis. The immediately subsequent period was one of increased development in the schools that had been giving petroleum industry instruction. At the Missouri School of Mines the petroleum option, which previously consisted of substituting courses in petroleum geology for some of the mining courses and oil and gas production courses (given at first by J. R. Guiteras, E.M. Col., 1911, and afterward by Edward McKee) was strengthened in 1922 by introducing a full year's course in organic chemistry. The next year the chemistry department introduced a petroleum-refining option into the chemistry curriculum. Guiteras left to go to Wyoming and McKee was succeeded by Marshall Graham in 1925, who was in turn followed by Eugene A. Stephenson in 1930. The curriculum was broadened and diversified, and in 1937 Stephenson went to the University of Kansas to become head of a petroleum engineering department there. He was succeeded by Gilbert W. Noble and in 1939 Horace T. Mann, who had been associate professor of petroleum engineering at M.I.T., went to Rolla as professor of that subject. The four-year curriculum was further modified, but Mann died shortly thereafter. In 1939–40 one third of all mining students were enrolled in the petroleum option.

University of Oklahoma.—At the University of Oklahoma (see p. 160) instruction for the petroleum industry began in 1924, when H. C. George went there to organize a department of petroleum engineering, which now has a staff of six men. George is almost certainly the man to whom most credit is due for placing petroleum-production instruction on an engineering basis. Up to that time the technical interest in petroleum was almost wholly that of "rock-hounds." George had had experience as a mining engineer and in the work of the U. S. Bureau of Mines, which prepared him to appreciate the engineering problems of petroleum production; he organized the department at the University of Oklahoma with that viewpoint, which was quickly accepted by others, and is now nearly universal. The department and others in the College of Engineering are there known as Schools. A School of Natural Gas Engineering is listed in current announcements, with the statement that its faculty consists of the members of the mechanical and petroleum engineering faculties, and a four-year curriculum is offered. The chemical engineering faculty seems to devote its major attention to petroleum refining, as would be natural in that area. The greatest student interest is in petroleum engineering, petroleum refining, and geological engineering, large numbers being enrolled in these curricula. The first two years of the mining and geological engineering curricula are the same.

University of Kansas.—At the University of Kansas, Erasmus Haworth, who was also State Geologist, was naturally interested in petroleum, but instruction followed the usual pattern of treatment of petroleum under geology and discussion of well drilling



PUMPING UNIT AND TYPICAL OIL-WELL "CHRISTMAS TREE," SCHOOL OF PETROLEUM ENGINEERING, UNIVERSITY OF OKLAHOMA.



PETROLEUM ENGINEERING LABORATORIES, UNIVERSITY OF OKLAHOMA.
Drilling and production equipment in foreground and complete refinery and lubricating-oil plant in background.

in the mining curriculum until 1924, when options in petroleum technology were offered in both the mining and the mechanical engineering curricula. Courses were offered in gas and oil production, oil-field engineering, and in oil and gas transportation. In 1930 a course in oil refining was offered by the mining department, as the chemistry department was reluctant to take it on. Eventually a separate department of Petroleum Engineering was established in 1937, and E. A. Stephenson became its head. A four-year curriculum leading to the Bachelor of Science degree is offered.

Johns Hopkins.—In 1924 L. I. Pollitt, then president of the Southern Gas Association, suggested that Johns Hopkins University (which had started an engineering school in 1912) should establish a department of gas engineering to furnish trained men for the gas industry. The original arrangement was that the Association should provide the necessary funds for five years, after which the University should take it over. Wilbert J. Huff (Ph.D. Yale, 1917, in charge of research Koppers Co., 1920–24) was put in charge of the department. Although the work was successful the University felt unable to take it over at the end of five years. Further support, amounting to as much as $15,000 per year, was secured, mainly from the American Gas Association and affiliated companies. A four-year curriculum leading to the bachelor's degree in gas engineering was offered, and advanced work as well, six doctor's degrees in this field having been granted.

Meanwhile the University had been endeavoring to establish a chemical engineering department, and when the second period of outside support terminated, in 1934, the only basis on which it felt it could proceed was by making gas engineering an option in the chemical engineering department. The accrediting committee of the Engineers' Council for Professional Development also did not look with favor upon a separate curriculum in gas engineering, so its present status is as an option in the chemical engineering curriculum. The department of gas engineering ceased to exist in 1937. It should be noted that this was not a department of natural gas engineering, but gas engineering in the more general sense.

Louisiana State University.—Louisiana State University began work in 1860 as the Louisiana State Seminary of Learning and

Military Academy, with Francis W. Smith filling the chair of chemistry, geology, mineralogy, and military tactics. During the years of development that followed various men taught geology and/or carried on a geological and topographic survey of the state. Gilbert D. Harris took charge of the latter work in 1898, with A. C. Veatch as his assistant. During 1901–2 Veatch was professor of geology in the University, but left the next year, and between 1910 and 1913 geology was not taught at all. Frederick E. Emerson was professor of geology from 1913 until his death in 1919. After another interregnum Henry V. Howe was made professor of geology, in 1922, with the intention of developing instruction to fit students for work in the petroleum industry. One of the first things done was to initiate extensive work at Shreveport, as well as a branch collection of maps, cores, cuttings, etc., there. This was so successful that it led the State Department of Conservation to finance a ceramic survey of the state, and to the establishment (1926) of a ceramics department, under John W. Whittemore, at the University. The petroleum and general geology work steadily expanded and in 1934 the State Geological Survey was reestablished, Dr. Howe being its director as well as professor of geology in the University. Since 1936 petroleum operators have been required by law to deposit cuttings and cores of all wells with the Department of Conservation for the use of the Survey, which has published a series of bulletins totaling nearly 3000 pages. In 1938–39 there were 284 students enrolled in the School of Geology, of whom 161 were majoring in petroleum engineering. Degrees have been granted to nearly 200 students, including four Ph.D. degrees. A new geology and petroleum engineering building has recently been completed.

The Pennsylvania State College.—At The Pennsylvania State College instruction in well drilling had long been given by the mining department and attention was given to petroleum in the economic geology course, but in 1923–24 a separate course in oil and gas technology was first given, and the geology of oil and gas was made a separate course at the same time. The latter course involved laboratory work in the processing and testing of petroleum. In 1929 the legislature appropriated $50,000 for research work in petroleum, and this was divided between the Schools of Mineral Industries and Chemistry, which undertook the work on refining. C. F. Barb was secured to strengthen the petroleum work in the geology department and a four-year curriculum leading to the B.S. degree in petroleum and natural gas engineering was offered in 1930. After 1931–32 petroleum work was organized separately, additional courses were added, and in 1935 C. A. Bonine, head of the department of geology, under whom this work had developed, relinquished its direction. S. J. Pirson was put in charge of petroleum instruction in 1936; C. R. Horn and S. T. Yuster also gave instruction, the other members of the staff being engaged in research. As a part of a general building plan, excellent laboratory facilities have been provided, and a 400-ft. cased and sealed well is available for tests. Much of the laboratory equipment has been provided through cooperation with the industry and manufacturers, through two advisory boards. A four-year curriculum leading to the B.S. in petroleum and natural gas engineering is being offered, and plans are under consideration for adding an optional fifth year.

The establishment of the petroleum engineering curriculum at The Pennsylvania State College was followed by the offering of a four-year curriculum in fuel technology in 1932. The first two years of all curricula in the School of the Mineral Industries are uniform. Specialization in Fuel Technology begins in the third and fourth years, when such topics as organic chemistry, physical chemistry, industrial chemistry, fuel testing and calorimetry, carburization and processing of coal, coal preparation, coal classification, petroleum characteristics, liquid and gaseous fuels, and advanced fuel technology are covered. The usual mechanical and electrical engineering of engineering courses is also included, and a number of courses in metallurgy, apparently because this curriculum developed out of the interest of the metallurgical department in fuels. The work in this field seems to be attractive to graduate as well as to undergraduate students, and no other school offers a similar curriculum.

University of Tulsa.—The University of Tulsa also had its origin in a denominational school. Various missionary bodies had long been carrying on educational work among the Indians in Indian territory, and in 1894 the Presbyterians merged three of their schools to form Henry Kendall College, at Muskogee. It was moved to Tulsa in 1907, the same year Oklahoma became a state, and in 1920 its name was changed to the University of Tulsa. In 1928 its control was placed in the hands of a self-perpetuating Board of Trustees, and during succeeding years some two million dollars was given it for buildings, equipment, and endowment. A school, now the College of Petroleum Engineering, was established in 1928, Waite Phillips having given $200,000 for an engineering building, and the first class of nine students was graduated in 1933. As now organized, there are six curricula; petroleum engineering (with production and refining options), geological engineering, aeronautical engineering, general engineering, and two leading to the degrees of Bachelor of Geology and Bachelor of Chemistry, respectively. Provision is also made for graduate work, leading to the master's degree.

University of West Virginia.—At the University of West Virginia active development began in 1928 of the petroleum and gas option in mining engineering it had been offering since 1915, and has steadily continued; further increases in the amount of professional work offered being made in 1936 and 1937. In the equipment provided for laboratory work, especial attention has been paid to natural gas engineering, since the value of the annual gas production of that state is more than eight times the value of its petroleum. An interesting feature is a three-day short course in the theory and practice of gas measurement and pressure regulation, for field men and executives, which has been held annually at the University since 1938.

Texas.—Education for the petroleum industry in Texas also dates from 1928, when F. B. Plummer was secured to head a department of petroleum-production engineering at the University at Austin, which thus resumed instruction in the mineral field which it had dropped with the discontinuance of its mining department in 1914. This work developed rapidly, and the department, of which the title was changed to petroleum engineering in 1937, now has three professors, two instructors, and an honorary lecturer. At about the same time petroleum instruction was started at the Agricultural and Mechanics Arts College, College Station, which had not previously offered mineral industry education. There also the work grew rapidly and four curricula are offered in this field, a four-year curriculum in petroleum engineering, a five-year curriculum in the same subject, a five-year geological option in the subject, and a five-year mechanical engineering option in the subject. This is perhaps the most clearly and highly developed case where mineral industry education is specifically directed toward a single mineral commodity, with instruction diversified by options in the technology fields applying to that commodity.

New Mexico School of Mines.—The New Mexico School of Mines established a four-year curriculum in petroleum engineering in 1936, the first two years being identical for mining, metallurgical, geological, and petroleum engineering. There is also a petroleum option in the geological engineering curriculum for the junior and senior years. B. I. Routh (M. S. Louisiana State University) is head of the department of petroleum engineering. In 1929 a $32,000 petroleum engineering building was constructed.

University of Southern California.—The University of Southern California was established by the Methodist Episcopal Church in Los Angeles in 1880 and gradually has grown into a large nonsectarian institution. It began to offer four-year curricula in civil and electrical engineering in 1905, and in 1912 a department of mining and chemical engineering, with L. J. Stabler as professor and L. S. Weatherby as associate professor, was announced. A curriculum in mining for the freshman and sophomore years was announced the next year; this naturally did not contain any advanced instruction. For some years thereafter the statement that the first two years of a mining curriculum were offered was all that appeared in announcements. Stabler later became professor of chemistry and dean of the College of Pharmacy. Mrs. Seeley W. Mudd gave the University a philosophy building as a memorial to her husband in 1932, and a library was subsequently acquired as a memorial to E. L. Doheny, so the institution has definite practical connection with mineral industries.

A College of Engineering was established in 1928, with six divisions; chemical, civil, electrical, general, mechanical, and petroleum engineering. Under the latter there is a four-year curriculum leading to the degree of Bachelor of Engineering, with a major in petroleum engineering. John F. Dodge, M.S., E.M., is professor of petroleum engineering. A three-year curriculum, leading to a certificate, junior grade, in mining is also presented; this may be amplified to a degree in general engineering by another year of prescribed work.

University of California.—The University of California established a branch at Los Angeles in 1919, but no engineering work is offered there beyond that which would appear in the first two years of any engineering curriculum. The only petroleum work offered is in petroleum geology. There were 180 undergraduate students majoring in geology at Los Angeles, and more than 20 graduate students in 1939–40. About 90 per cent of the undergraduate majors and probably 100 per cent of the graduate students look forward to a career in petroleum geology, according to E. K. Soper, formerly dean of the School of Mines, Oregon, and now professor of geology at U.C.L.A. The curriculum in geology is essentially the same as at Berkeley. Fundamentals of geology, especially structural geology and field geology, are stressed, and specialization in petroleum geology is given in the senior year and in graduate courses. Detailed field mapping in the oil-producing areas of the state is required, subsurface geologic correlation, geological aspects of electric coring, and related subjects are taken up, and the students have an exceptional opportunity to observe the application of geologic principles in petroleum exploration and development because of their proximity to many producing fields.

Branches of Petroleum Instruction

Considering this review of the development of instruction for the petroleum industry in perspective, one of its most striking features is that it grew so slowly for such a long time, and then developed with extraordinary rapidity. During the first 50 years of the past three quarters of a century it showed hardly any progress, while in the next 25 years it developed rapidly, especially since 1925, when the engineering viewpoint was added to the geological one. In 1927–28 about one tenth of all students of mineral industry curricula were in those dealing with petroleum, in 1936–37 over one third of all mineral industry students were so enrolled. Various explanations may be offered for this; my own is that the petroleum industry applied a first stimulus through hiring many petroleum geologists, and a second through becoming willing to pay liberally for the services of technically trained men to work in oil-field production operations.

The educational developments tend to corroborate this view, for geological departments were typically the first to become interested in specific and advanced instruction in the petroleum field. The typical petroleum curriculum is now, however, engineering rather than geological.[1] This is a redeeming feature of the otherwise alarming sudden increase in production of graduates in this field. Where curricula have a broad and sound basis of the fundamentals of all engineering, graduates will be able to fit themselves to almost any form of industrial activity, as the early graduates of mining curricula so frequently did. Petroleum engineering seems likely to establish itself as a curriculum that will furnish a general engineering education, especially in regions where petroleum production is the dominant economic activity of that geographic area. Engineering instruction for the petroleum industry was dropped in Boston (M.I.T.) while in the New York area nothing has been offered beyond a course in the fuel technology of solid and gaseous fuels, given in the chemical engineering department, and one on the geology of oil and gas, given in the geology department at Columbia. Only petroleum geology instruction is given in the Los Angeles branch of the University of California, though the University of Southern California has a curriculum in petroleum engineering, described previously in this chapter. Chicago and St. Louis institutions have not entered the petroleum field. Large institutions in large cities may properly offer some general instruction in this field, but unless the city is in a petroleum area there seems no valid reason for offering specific petroleum engineering curricula.

The situation in regard to petroleum geology is not so clear. It is obvious that every economic geologist should have an adequate knowledge of the two mineral substances that are mined in greatest volume and have the greatest influence, through the production of power, on the general economy. Where the associations of the geology department are mainly with a mining or engineering school this basic relationship will naturally be emphasized, while in geology departments that are essentially depart-

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* For a more detailed discussion of the scope and content of petroleum engineering curricula than is possible here, see the papers of references 46, 59 and 62.

ments of pure science it will be less stressed. In areas where there is considerable local demand for petroleum geologists there is a valid reason for a definite curriculum in that subject. But since it will be necessary to consider geology in its relation to mining, geophysics, and engineering in a later chapter, further discussion may best be deferred until it can be considered in all its general relationships.

There is a sharp difference of opinion as whether petroleum refining is a branch of the general subject of chemical engineering rather than the proper basis for a curriculum leading to a degree in petroleum refining. After several years experience in offering such a curriculum, the University of Pittsburgh decided to discontinue it, making it an option in chemical engineering. At the University of Oklahoma the major interest of the chemical engineering department is in petroleum refining; this is a logical development in an area where the principal, perhaps almost the only, field of employment for chemical engineers is in petroleum refineries. There is room for difference of opinion as to how useful the laboratory equipment necessary for detailed study of petroleum refining can be made for the more general treatment of chemical engineering principles. The specific curricula that may be usefully offered should, in general, be determined more in the light of its economic geography rather than from abstract educational principles. It is true that a student should endeavor to keep the field of possible useful employment for his qualifications as wide as possible. As a chemical engineer who has majored in petroleum refining, he may secure a position in a petroleum refinery if that is his immediate objective, and possibly make that his life work—but, if, for any reason, he should later find it necessary to seek other employment a wider field will be open to a graduate chemical engineer than to a graduate in petroleum refining. On the other hand, if he expects to make a career in petroleum, he is perhaps more likely to rise to a high position if he has specialized in that field. The petroleum industry is definitely recognized as a major subdivision of the mineral technology field, and refining, though on the borderline, belongs there too.

Chapter 12

SPECIAL CURRICULA OTHER THAN PETROLEUM

IT does not seem practicable to review all the other specialized curricula that have developed in the mineral industries field in so much detail as has been given for petroleum. Nor is it easy to draw a definite line between true curricula, leading to a designated degree in the special subject, and options, which may range from the mere substitution of one or two courses for others in the final years to differences so extensive as almost to amount to separate curricula. Even to attempt to catalogue all the options that have been offered at one time or another would require too much space. The remainder of this discussion, therefore, will be confined to three topics which seem to be of major importance. Mining and metallurgical curricula will be covered in a later chapter.

Geology

The first, from the historical view, is geology in its relation to the mineral industries. Previous chapters have made clear that in the early years of mineral industry instruction in the United States economic geology and mining engineering so overlapped one another that men who were by training and experience economic geologists were appointed professors of mining, while men who had graduated as mining engineers sometimes developed into professors of geology. Even today men whose basic training was in geology as a pure science, and who perhaps took a doctor's degree in that subject, have attained such distinction in the mineral industries as to be universally accepted as "mining men," and their right to be regarded as mining engineers would not be questioned, even though they did not take a degree in engineering. Nevertheless the distinction does exist, and has been made a concrete reality in recent years by the enactment of state laws which require engineers to be licensed. There have been some absurdities in the applications of these laws; I know of one geologist employed by a state board who, although he had had no engineering training and did not profess to be an engineer, was required by his employers to apply for an engineer's license, and had no difficulty in obtaining it. But it seems clear that licensing laws are here to stay, that regulations under them will eventually become so clarified that to obtain an engineer's license a man must have had technical training in engineering, and that eventually a clear distinction will be made between geologists who are also qualified as engineers, and the pure science geologists, even though the latter are engaged in applying their science to the problems of mineral industry.

It was stated in chapters 5 and 8 that Columbia School of Mines offered a separate curriculum* leading to the Ph.B. degree in geology as early as 1868, but that this curriculum never attracted many students, virtually all Columbia graduates who became prominent in the field of mining geology having taken the mining curriculum. James F. Kemp, who was long the head of its geological department, a member of the National Academy of Science, and an economic geologist of international reputation, graduated as a mining engineer in 1884. Roland D. Irving was an earlier (1869) graduate in mining engineering who became an outstanding geologist, and many more might be named. Columbia did not offer a mining geology option until 1919–20 (though 20 years previous it had been possible to substitute an additional course in geology for one in mechanical engineering in the fourth year) but it still led to the Engineer of Mines degree; it was changed back to a final-year option in the mining curriculum in 1927–28, and now differs in the final two years.

This development was not typical of other schools, which had nearly all dropped the Engineer of Mines as a degree to be awarded in course, and were offering four-year curricula leading to the B.S. degree. Mining geology became in some schools a fourth-year option in the mining engineering curriculum, and in others a separate curriculum leading to B.S. degree in mining geology. The latter is not necessarily an engineering curriculum, though in most cases it contained some engineering courses.

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* This curriculum was dropped in 1890–91.

The first B.S. degree in mining geology at Penn State was given in 1912. It has not been possible to ascertain when the first one was given anywhere in the United States. The engineering content of these curricula was not called in question until the Engineers Council on Professional Development began accrediting engineering curricula in 1935. In some cases it was easy to determine that curricula contained enough engineering instruction to be accredited as such, and in others it was clear that they were not engineering curricula, but some presented difficult questions to decide. This may be illustrated by one specific case.

Chemistry and Natural Philosophy was taught at Princeton from 1795 to 1812 by John Maclean. Henry Vethake gave the work in 1817, but went the next year to Columbia, where his interest was thereafter mainly in economics. Jacob Green and Luther Halsey succeeded him at Princeton, and John Torrey, who later was so important in the development of the School of Mines and the department of botany at Columbia, held the chair from 1830 to 1854. That year Arnold Guyot became professor of geology and physical geography and continued for 30 years. In 1872, when John C. Green gave Princeton $200,000 for developing its work in the field of the natural sciences, John Stilwell Schanck was professor of chemistry and natural history, Cyrus Fogg Brackett was professor of physics, and H. B. Cornwall taught analytical chemistry and mineralogy.

The John C. Green School of Science was established, and, in addition to other curricula leading to the B.S. degree, one leading to the Civil Engineer degree was announced in 1875. They attracted student interest and the curricula were steadily strengthened both as to entrance requirements and work offered. A curriculum in electrical engineering was announced in 1889–90, which eventually developed under Brackett into a two-year course of graduate work, civil engineering remaining as a department in the Green School. In 1905–6 electrical engineering was restored to the Green School, still as a graduate course, first as a department and then apparently as a subschool. In 1908–9 it appeared as a separate school and this relationship persisted until 1921–22, when a School of Engineering was established, offering four-year curricula in civil, mechanical, and electrical engineering leading to the degree of B.S., though the School of Electrical Engineering on a graduate basis was retained until 1922–23.

In 1922–23 additional curricula in chemical and mining engineering were offered, the latter being essentially the civil engineering curriculum with advanced civil engineering work replaced by mineralogy and geology, plus a course in physical metallurgy given by the chemical department. For many years thereafter the entire geological department appeared in the Princeton catalogues as the department of mining engineering, though none of the staff were mining engineers. Three courses in metallurgy—iron and steel, alloy steel and alloys, and nonferrous metals—were listed at first, with no indication who taught them, but eventually were dropped from the catalogues. In 1935 the name of this curriculum was changed to Geological Engineering. The only instruction offered in metallurgy is a course on metals and alloys given by the chemistry department; no mining engineering instruction, strictly speaking, was ever offered. The changing of the name of the curriculum represents the final clearing up of the confusion, which long existed in many quarters, as to the relationship between economic and applied geology, and mining engineering.

This introduces a new field, geological engineering, which is not at all identical with mining geology. The importance of geological considerations to civil engineers in the design and construction of large works, such as subaqueous tunnels, water-supply conduits, and bridge and dam foundations, had long been recognized; the appointment of Professor Kemp as geological consultant to the New York Board of Water Supply made this relation evident, and the later work Prof. Charles F. Berkey did as a consultant to the Federal Government in connection with numerous power projects brought it to wide public attention. In the schools the civil engineering departments began calling upon geology departments to offer courses more directly aimed at the needs of civil engineers, while geologists began paying more attention to those geological problems that are of importance to civil engineers. One or two textbooks on engineering geology have been published, and some schools began offering curricula, variously entitled geological engineering or engineering geology.

It was natural, perhaps, that little attention was at first paid to the distinction in meaning of the two expressions, geological engineer and engineering geologist. There is no general agreement as yet as to the amount of technical engineering knowledge an engineering geologist should have, nor as to how much special geological knowledge a geological engineer requires. It might even be questioned as to whether geological engineering lies in the field of mineral industry education, since it does not deal with minerals from their use as such, but only considered as engineering structural materials. It is the view of the writer that the most helpful cooperative relations exist where a geological department is associated with mining and metallurgical departments in a College of Mining, Mineral Industries, or whatever the academic subdivision may be called, for these borderline fields will then be more adequately covered. If a geologist does not have a sound knowledge of the mechanics of materials he is not a geological engineer. Curricula where geologic training is imposed on a sound engineering foundation appear to be the proper training for this field of work.

Restating the problem, geologists in the early days knew enough simple engineering to function as mining engineers, while mining engineers knew enough geology to function as mining geologists. The subsequent trend has been toward a separation between mining engineering and geology, a geologist needing to know more of that immensely developed science than is practicable to incorporate into a four-year mining curriculum, which is also too brief to contain all the necessary mining engineering instruction and sufficient geology to qualify an individual both as a mining engineer and a mining geologist. We can now have mining engineers who know some geology, and geologists who know some engineering, but the way to simultaneously qualify in both fields is becoming increasingly hard to follow.

GEOPHYSICS

Meanwhile another complexity has arisen through the development of geophysical methods of exploration. It is difficult to assign a date of origin to them—knowledge of the earth's magnetism goes back many centuries, and determinations of the pull of gravitation, of the point of origin of earthquakes, and the detection of electric potentials in ore bodies are more than a century old—but it may be said that except for surveys with the magnetic compass little practical use of them was made until after the World War. Possibly it was the application of similar techniques to military problems during that period which awakened interest in their possibilities if applied to ore-finding, but whatever the cause there was a general flare-up of interest in them immediately following the war. Electrical techniques developed in France were applied in the United States and Canada in 1921, and seismic-wave experiments were made in Oklahoma the same year. E. de Golyer and D. C. Barton began using a torsion balance to search for structures favorable to petroleum accumulation in 1922, and shortly afterward de Golyer organized the Geophysical Research Corporation to apply seismic-wave methods in the search for salt domes. Within a few years an enormous number of publications on the subject began to appear, the American Institute of Mining and Metallurgical Engineers issued its contributions in a separate volume, and a Society of Exploration Geophysicists was formed. No sharp distinction between geophysics as a science and its applications to mineral finding was made, some of the workers in the field were physicists or electrical engineers who had turned their attention to this new development and many others were geologists. It soon became clear that there were two main aspects; the physical techniques involved in making the determinations and the interpretation of their significance in terms of geology.

The reactions of the schools to this new technical interest were diverse in the extreme. At Colorado School of Mines a separate department of geophysics was established in 1926, with Carl A. Heiland (Sc.D. Hamburg) as its head. This now offers 10 courses in geophysical prospecting, a number of them involving laboratory work as well as lectures. Geology-geophysics is an option for the last two years of the geology curriculum.

The other institutions were much more cautious in their approach to this new problem in mineral industry education. At Massachusetts Institute of Technology, F. L. Foster, who took his degree in 1925, joined the staff of the mining department and developed geophysical prospecting instruction within it, as well as giving some of the mining lectures. At Columbia the geology department appointed M. K. Hubbert, who had taken his Ph.D. in both physics and geology at Chicago University, as an instructor in 1930 to give instruction both in geophysics and geology, while the mining department included geophysical methods in its general treatment of prospecting methods. At some schools it was the physics department that began to give attention to geophysics, and at still others it was the electrical engineering department which began to take an interest in the subject. It is impracticable to mention all the schools, but what has been said will serve to indicate the range of educational development.

A much more detailed discussion of the educational problems involved can be found in the proceedings of the round table discussion on geophysics education and exploratory geophysics as a career which was held during the A.I.M.E. meeting in February 1938. One of the papers of especial interest, by Donald C. Barton, a pioneer in the field, expressed the view that young men in petroleum geophysics would, in general, have to look forward to becoming eventually either operating men or petroleum geologists, and should pattern their basic education on that assumption. He further said, "The future for men holding only bachelor's degrees seems distinctly poor, except for a few men who take exceptionally well to foreign work." He believed that within, say, 10 years they would not be able to get work in geophysics and could not transfer to some other phase of the company's activities without complete loss of rank, so it would prove a dead end for them. One employer of many workers in this field said that he would prefer that they should have no special geophysical instruction in school, since schools can never keep up with the latest developments of field practice; therefore young men soundly grounded in physics and geology were easier for him to develop than those who thought they already knew the subject of geophysics and its applications.

On the other hand, Barton expressed the view that a sharp distinction should be made between men who intend to become professional geophysicists and those who have only a collateral interest in geophysics, claiming that "All geologists and mining engineers should have an elementary knowledge of the geophysical methods of mapping geologic structures." The writer's view has always been that geophysical methods of exploration are much like the use of X-rays in diagnostic medicine. Their possibilities were first worked out by specialists in the field, and still continue to offer a field for research to a relatively small number. Their practical application in diagnosis involves technicians who make the necessary observations, and diagnosticians who interpret them. Every practicing physician needs to know enough about X-ray diagnosis to know when to call for an X-ray. It seems plausible to expect that a generally similar situation will gradually develop in the mineral industries as regards geophysical methods of exploration. On that basis the logical locus for instruction in applied geophysics is in the schools which offer instruction for the mineral industries, and more specifically, either in their geological or mining departments, or both cooperating, as qualified personnel may indicate.

CERAMICS

Ceramics* is both an art and a technology; both phases of it dating back to an early period. Clay was worked as early as the Late Stone Age, in the present view of archeologists; thus ceramics is older than metallurgy, though not as old as the mining of flint. Glassmaking began as early as seven or eight thousand years ago. The practical art and technology long ago reached a high degree of perfection. Porcelain-making in China had by the tenth or twelfth century produced as fine porcelains as can be made. These were the product of skilled workers and artists. Until the beginning of the eighteenth century very little was written on the subject of ceramics, and even that seldom went beyond the description of products or the publication of so-called secret formulas.

Commercial contact between China and Europe after the seventeenth century made the western world conscious of a ceramic art far in advance of its own, and by the end of that century virtually every crowned head in Europe had put subsidized alchemists to work attempting to duplicate the Chinese product. A German alchemist named Boettger, in the employ of Augustus the Strong (with whom we are already familiar for his part in the founding of mineral industry education), succeeded in 1709. The world's first ceramic technologist and research worker, Josiah Wedgewood, appeared in England in the middle of the eighteenth century, but since he kept his results secret they contributed nothing toward scientific advancement. His example was followed by others, and advancement, which generally was restricted to the production of pottery and dinnerware, was kept secret for some time.

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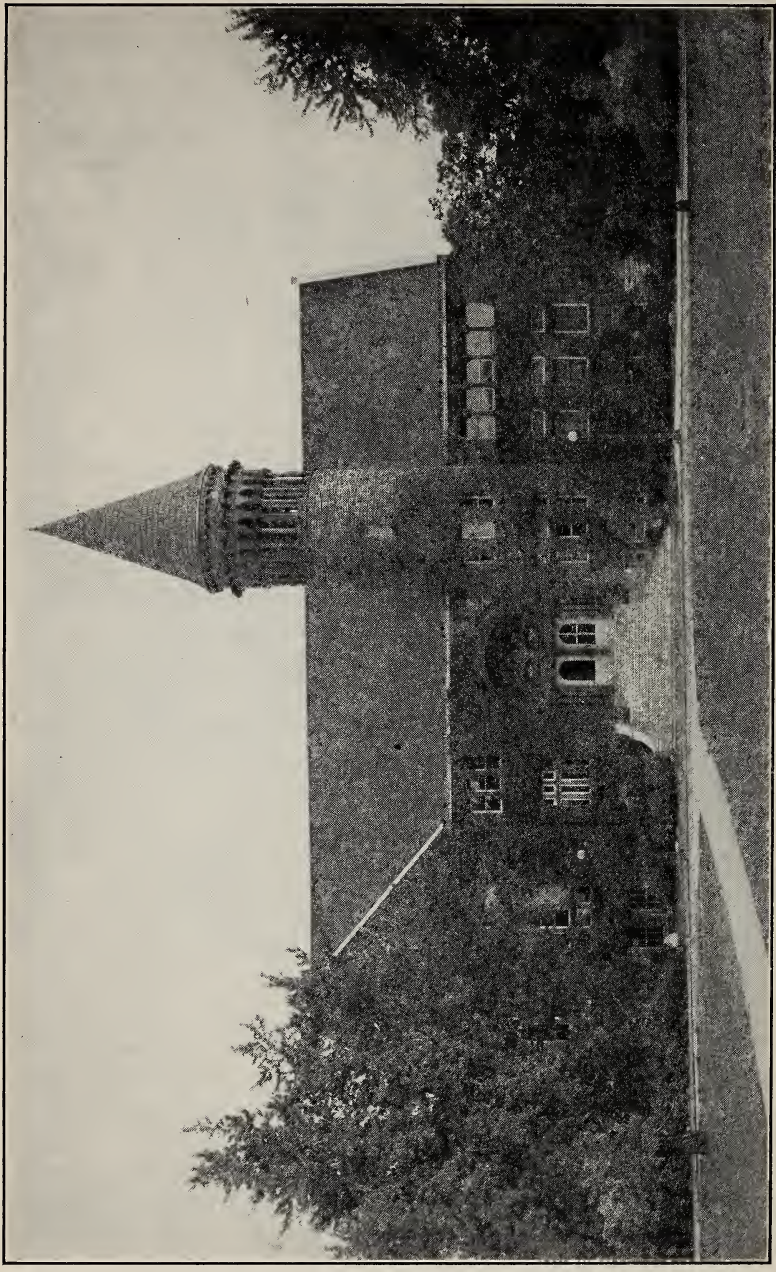
* I am indebted to Dr. A. F. Greaves-Walker, professor of ceramic engineering at the University of North Carolina, and former president of the American Ceramic Society, for much of the material of this section.

In 1830 A. Brongniart began publishing in France the first articles on ceramics which are of any real scientific interest. In Germany after 1860, C. Bischof and H. A. Seger began publishing the results of their ceramic researches, which are the foundation of modern ceramic technology. In this country the first attempts at education and research in ceramics were the results of the efforts of Edward Orton, Jr., son of the first president of the Ohio Agricultural and Mechanical College, now the Ohio State University (see p. 96).

Edward Orton, Jr., had taken the E. M. degree at that College in 1884, and had been associated with his father (who became State Geologist in 1882), thus becoming interested in the nonmetallic mineral resources of his state. He spent four years after graduation as a chemist and superintendent of iron blast furnaces and the following six years in the heavy-clay industry. In 1894 he undertook to promote the first department of technical ceramic training in this country, and that year the legislature of Ohio authorized the establishment of a department of clay-working and ceramics at Ohio State University. Edward Orton, Jr., was appointed its director and professor, and the department was housed in the west half of Orton Hall, a building erected from Ohio building materials as a memorial to his father.

The first course of study was a two-year curriculum of a practical nature, based on the assumption that the problems of ceramics were subject to control through the principles of chemistry; thus especial stress was placed on chemical education. Orton soon realized that the necessary instruction could not be provided in two years, and in 1896 a four-year curriculum was planned, to be correlated with the other departments of engineering education. The first graduate received the degree of Engi-



Orton Hall, Ohio State University. Erected 1894.
The first ceramic technology instruction in the United States was given in this building.

neer of Mines in Ceramics in 1900. This degree continued for about eight years, the degree Ceramic Engineer was substituted for a few years, and was then changed to Bachelor of Ceramic Engineering, which has since been granted.

Professor Orton's teaching equipment was original, since he had no precedents to guide him. It consisted of brickmaking and pottery-making machinery provided by manufacturers as gifts to the department; only the chemical laboratories were equipped in the usual manner. The only American text available was "The Chemistry of Pottery," by Karl Langenbeck, who had been connected with the Rookwood Pottery, the American Encaustic Tiling Co., and the Mosaic Tile Co. This was published in 1895 by the Chemical Publishing Co., of Easton, Pa. English literature contributed little of a technical nature and owing to the confusion in terminology and weights and measures the American investigators had little success in using such English information as was available. Orton used Seger's works as the basis of his courses, began the manufacture of pyrometric cones for the regulation of firing temperatures, and developed laboratories and a testing station for the study of clay. Probably he was the first American to realize clearly that the production and utilization of nonmetallic minerals represented a huge potential field for engineering services. Mining schools and mining engineers then had very little interest in nonmetallic minerals, and he conceived the idea of splitting the mineral field; the nonmetallic minerals to be the province of the ceramic engineer.

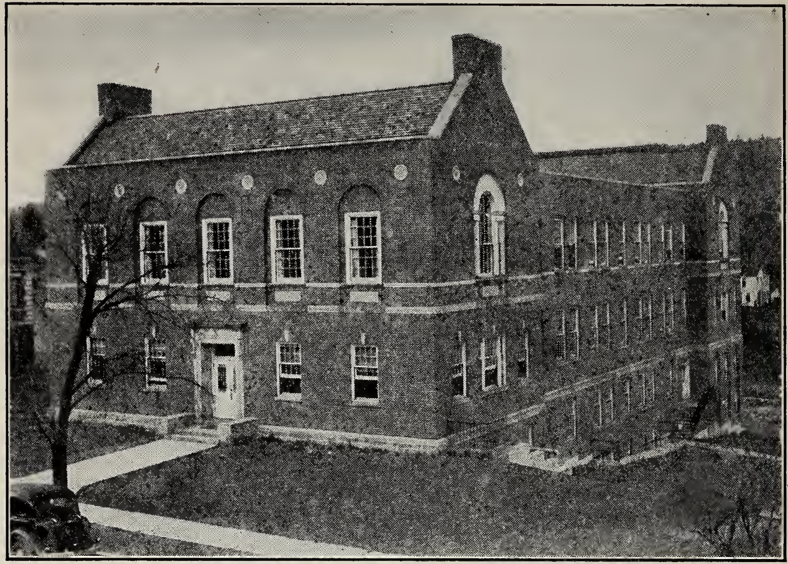
This view did not at first prevail, however. The word "ceramics" at that time was used only to designate pottery and a limited number of other clay products, and the technologists in the ceramics field had no sense of kinship with mining engineers; nor did the mining engineers feel related to the ceramics men. Professor Orton organized the American Ceramic Society in 1899 and served as its secretary and editor until 1912. The ceramic technologists took some time to come around to Orton's view that the field of ceramics should cover all the nonmetallic industries except the fuels—a sort of nonmetallic metallurgy. The curricula at the other schools, which were soon established, gradually came to conform to Orton's view.

Lord Hall, Ohio State University. Erected 1906.
Provides facilities for departments of Mining and Ceramic Engineering.

The next ceramics department to be established was at Alfred University (New York State College of Ceramics) in 1900; it was followed by one at Rutgers University in 1902. The University of Illinois and Iowa State College established their departments in 1905; the University of North Dakota followed in 1910; and the University of Washington in 1918. The departments at Pennsylvania State College, the University of North Carolina (North Carolina State College), and Georgia School of Technology were established in 1923; Louisiana State University and Missouri School of Mines established their departments in 1926; and Virginia Polytechnic Institute in 1928. Graduate courses in ceramics are offered by the metallurgy department at Massachusetts Institute of Technology, and courses in either ceramics technology or ceramics engineering are offered at West Virginia, Purdue, Pittsburgh, Alabama, and several other universities. It will be noticed that all the institutions which offer such instruction are either in states that have important ceramic industries, or are important producers of ceramic raw materials.

Since Alfred University is the only institution where ceramics is organized as a separate college, the following description, taken largely from a paper presented by its dean, M. E. Holmes (B.A., M.A., Ph.D., Cornell, 1918) at the A.I.M.E. meeting in New York, Feb. 16, 1941, will be of interest. The establishment of a New York State College of Clayworking and Ceramics was authorized by the legislature in 1900, with an initial appropriation of $24,000 for building and equipment. It began work with one instructor and five students. Charles F. Binns was its first director and remained in that post until he retired in 1931. During his administration emphasis was laid on the training of teachers of ceramic design, though engineering and ceramic art were also covered.

In 1932 the name of the school was changed to New York State College of Ceramics and the title of its head from "director" to "dean," and Dr. Holmes was appointed to this post. A new building, with corresponding equipment, was constructed, at a cost of a quarter of a million dollars, a department of glass technology was established and a four-year curriculum leading to a B.S. degree in glass technology (the only one in America) was added to the existing one in ceramics. In addition to these two curricula there is a four-year course in Industrial Ceramic Design, leading to the B.A. degree, which is essentially a fine arts course. Four B.S. degrees, however, were given in 1939 to students who had majored in applied art. The professional degree of Ceramic Engineer is given to holders of an engineering degree who after four years of industrial experience have demonstrated superior ability in ceramic engineering.



New York State College of Ceramics, Alfred University.

The research done by the faculty in the field of ceramics was officially authorized and extended, in 1936, by the establishment of a N. Y. State Ceramic Experiment Station as a department of the College of Ceramics. Five men now devote their whole time to ceramic research, which is supplemented by the teaching faculty and forty or fifty senior students. Fellowships worth from $600 to $3000 per year have been established by a number of ceramic corporations or associations. This department renders free research development service to the ceramic industries of the state, making its results generally available through bulletins and articles in technical journals. The direction of the research program is in close collaboration with the Board of Directors of the Ceramic Association of New York, and for this reason applied, rather than industrial or fundamental research, is given emphasis, though the amount of the latter is increasing. The College now has an annual budget of $140,000, a staff of 14, and a student body numbering 330. Twenty-three B.S. degrees in ceramic technology and engineering, and 16 B.S. degrees in glass technology were granted in June 1939.

During the first 20 years that instruction in ceramic engineering was offered in the United States the number of graduates was small, but it has been steadily increased and something over 1500 such degrees have already been granted. The first branch of the ceramics industry to recognize the value of technology and engineering was the refractories industry, probably because its products are largely used by metallurgical engineers, who insist on dependable materials. The glass and cement industries had long been employing chemists for the control of their raw material. The glass industry only gradually recognized the value of special training, but since the ceramics curricula have come to include courses in glass technology their graduates have won a recognized place in it. The cement industry still largely depends on chemists. The men technically trained in ceramics gradually found a field for themselves in the structural clay products, enameled metal, lime and plaster, insulating material, abrasives, dental porcelain and cement, and other special branches of the ceramics industry, where they are employed not only in production but in engineering research and sales as well.

The trend in ceramics curricula has been toward keeping a broad basis of fundamental engineering and science. Besides such studies as mathematics, physics and chemistry, they cover mineralogy (including optical and thermomineralogy), geology, physical chemistry, surveying, and electrical and mechanical engineering. The specialized courses cover the fundamentals of winning, processing, drying, and firing of ceramic materials and products, the characteristics of structural-clay products, glass, whitewares, refractories, enameled metals, and other products, and the design and operation of ceramic equipment and plants. Many of these plants are too small to employ a large technical staff, and the ceramic engineer may find it necessary to cover every aspect from the operation of a small mine to controlling raw materials and finished products, combining with it such research and development work as he can find time for. He is thus rather like the old-fashioned mining engineer who had to be geologist for his mine, construct and operate an ore-dressing plant, construct and operate a metallurgical plant, and do research and development work in all these fields. The trend toward more extensive use of a research staff in the ceramics industry, the development of research in departments of ceramic engineering in educational institutions, and the establishment of publicly supported ceramic engineering experiment stations is developing ceramics technology to such a high level that it is not improbable that there will develop a demand for optional and more diversified curricula.

Meanwhile the ceramic engineers* appear to have come to recognize that their natural affiliation is with the American Institute of Mining and Metallurgical Engineers, the national society of the mineral industries. The Industrial Minerals Division of the A.I.M.E. is made up of ceramic engineers as well as mining engineers and geologists whose chief interest is in the nonmetallics field, while ceramic engineering educators are active in the Mineral Industry Education Division of the A.I.M.E. On the other hand, mining engineers and metallurgists also recognize their kinship with ceramic engineers. Ceramic engineering therefore is a recognized branch of mineral industry education and at the present time about half as many students are pursuing curricula in this field as are enrolled in mining engineering curricula.

MINERAL DRESSING

The mechanical preparation of minerals for metallurgical treatment is another ancient practical art, and Diodorus Siculus quotes a description (now lost) by Agatharchides (who lived in the second century B.C.), which tells how the Egyptians of his time crushed and washed gold ore to recover its metal content;

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* The approved definition of their field is as follows: "Ceramic Engineering is that branch of engineering concerned with: (1) the mining, refining and processing of minerals and rocks except coal, oil, and ores as such; (2) the manufacture of products therefrom; and (3) the design and construction of the necessary equipment and structures."

inscriptions on Egyptian monuments dating almost four thousand years earlier also refer to gold-washing.* It seems logical to infer that gold-washing was one of the earliest of human mineral activities. Before the third century B.C. mechanical concentration processes had been applied to the silver-bearing lead ores of Mt. Laurion, Greece. Book VIII of Bauer's "De Re Metallica" (1556) describes (pp. 267–351) "The methods by which the ores are sorted, broken with hammers, burnt, crushed with stamps, ground into powder, sifted, washed, roasted, and calcined." The next book says that since he has covered "the varied work of preparing the ores, I will not write of the various methods of smelting them." This divides the mineral sequence into three parts, the mining of the ores, preparation for smelting, and smelting them. It will be noticed that while the methods of preparation were mainly mechanical, and the smelting operations involved chemical change, the distinction was not on that basis, but was between preparatory operations and final finishing ones. The German expression for this branch of the mineral arts was *aufbereitungskunde,* which emphasizes the idea of preparation. The English expression is ore dressing; dress also signifying preparation, as to dress a fowl for cooking.

In ways too devious for us to attempt to trace, ore dressing gradually came to signify only "the preparation of ores for the smelter by mechanical means," as R. H. Richards defines it in his "Ore Dressing";† this definition is confirmed by Taggart in his Handbook of Ore Dressing (1927), who said "Ore dressing is the art of mechanical treatment of ores to produce concentrate and tailing." The French expression "préparation mécanique," always had this significance. As taught in educational institutions in the United States, until very recent years, it was a description of mechanical preparatory operations and of the equipment used to perform them, and gradually came to deal more and more with the principles underlying them. As such it was usually taught by the same person who gave the mining instruction. Probably the fact that ore dressing typically is done at the mine, and often physically separated from smelting operations, which may be miles distant, had something to do with this association of fields. At any rate the tradition grew up that ore dressing was something to be taught by the mining department, and since that department otherwise dealt with mechanical operations the trend toward regarding ore dressing as a purely mechanical operation was probably accentuated.

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* De Re Metallica,[1] 279.

† The publication of this work, in two volumes, in 1903 was almost as much of a landmark in mineral technology as Bauer's work in the sixteenth century. Two more volumes appeared later, and eventually, with the assistance of Earl S. Bardwell and E. G. Goodwin, it was summarized in a one-volume "Textbook of Ore Dressing" in 1909. Professor Munroe, at Columbia, was also contributing the development of the theory and practice of ore dressing contemporaneously with Richards, while Gaetschmann, Rittinger, Linkenbach, Bilharz, Kirschner, and others had contributed extensively to European literature on this subject at a much earlier date (Gaetschmann's "Aufbereitung" appeared in 1864). But it is not too much to say that Richards' work was of controlling influence both in the practice and the teaching of the art in the United States. Richards was from the first assisted by Charles E. Locke, who carried on the work after Richards retired.

Meanwhile forces that eventually would cause a change in viewpoint had long been at work. Ore dressing was the preparation of ore for smelting operations; from very early times some ores had not been smelted, but subjected to hydrometallurgical processes which employed many of the same techniques as in ore dressing. The development of the cyanide process for gold recovery after 1890 made the crushing of ore and the handling of the crushed material of major importance in a metallurgical process, and great progress was made in the development of better equipment and new techniques. Thus the dividing line between metallurgy and ore dressing became less distinct, an effect that was accentuated after 1900 by the development of the froth-flotation process in ore dressing. Physical chemical rather than mechanical forces play the major role in that process, which quickly became widespread and is clearly one of the major developments that have taken place in the mineral industry. The rapid development of chemical engineering during the same period involved the use of equipment and processes so closely akin to those of modern ore dressing that there developed a tendency toward covering in the chemical engineering department much of the same ground traversed in ore-dressing instruction. Ore dressing now is much more closely related to metallurgy than it is to mining.

Recognition of this situation led Prof. A. F. Taggart to urge the introduction of a separate curriculum at Columbia to replace the older system under which a student who specialized in an ore-dressing option received a mining or metallurgical engineering degree. The new curriculum, leading to the B.S. and M.S. degree in mineral dressing provided time for more thorough and advanced instruction in physical and organic chemistry, and other basic subjects by dropping mining and such part of the metallurgical instruction as did not deal with the extraction of metals from ores. This was announced in 1934–35. The experience of the next five years indicating that this view of the problem was essentially sound, a further revision of the curriculum was adopted and announced for 1940–41. The aim of this new curriculum, as stated by Professor Taggart, is to train its graduates in the methods used or available for dressing the crude minerals comprising the crust of the earth into the primary derivatives which constitute consumer materials. The three ideas underlying the curriculum are that the technology involved is broad enough to constitute the subject matter of a separate branch of the engineering profession, but not so diverse or complicated as to be beyond the ability of an average student to comprehend; that the industries involved employ enough men and are of sufficient diversity substantially to ensure initial employment for graduates; and that the methods of the three principal branches of dressing mineral crudes sufficiently overlap, both in principle and practice, so that if a worker in one is forced to transfer to another he can reap economic benefit from his previous experience. The course content comprises the fundamental science and elementary engineering subjects common to all good engineering curricula and roughly equal amounts of specialized instruction in ore dressing, extractive metallurgy, and petroleum refining. When announced at the February 1940 meeting of the Education Division of the A.I.M.E. it was the latter feature of it which was received with most hesitation. However, Professor Gaudin, of Massachusetts Institute of Technology, expressed the view that the proposal was not so revolutionary as it might at first seem, and that the final result of similar curriculum changes being made at his own institution would probably not differ greatly from what was thus offered. It is certainly in the sound mineral industry education tradition to try new ways of doing things, and await the verdict of experience as to the practical wisdom of the change.

Chapter 13

RECENT MINING AND METALLURGICAL EDUCATION

IT will be recalled that the first professor of metallurgy in the United States, appointed in 1855, never really gave any instruction in metallurgy and gradually turned into a professor of mineralogy. Metallurgy was included with mining in the early curricula, two students who took the B.S. in mining engineering from the Polytechnic College of Pennsylvania in 1862 wrote their graduation theses on the metallurgy of copper and zinc, respectively. Even after Columbia School of Mines established, in 1868, a separate curriculum leading to the Ph.B. degree in metallurgy, very few students elected it,* preferring to take the mining degree, since they received in its curriculum nearly all the metallurgical instruction they would have in the metallurgical curriculum. For many years a large proportion of the men who attained prominence in metallurgical enterprises had taken mining rather than metallurgical degrees.

Metallurgy

Clifton Sorby's study of thin sections of rocks under the microscope, beginning in 1850, and its subsequent development by Zirkel and others, had made microscopic petrography a recognized department of geological research as early as 1873. It was inevitable that the idea of studying polished metal surfaces under the microscope by reflected instead of transmitted light would occur to investigators. Sorby himself did it in 1864, and Adolph Martens and Floris Osmond may be especially named among the many European workers who, by the late eighties, had so developed the necessary techniques that they were able to photograph polished metal surfaces at magnifications as high as 300 diameters. This new development did not at first attract much attention in the United States. Dr. Alexis Julien and Joseph Struthers made some tentative beginnings on microscopic study of metals at Columbia School of Mines, and during the late eighties Henry M. Howe, then serving as a special lecturer in metallurgy at Massachusetts Institute of Technology while carrying on a consulting business in Boston, was accustomed to refer to the work of Osmond and others in his lectures. Albert Sauveur, who took his B.S. at M.I.T. in 1889, was employed by the Illinois Steel Co. about a year later and assigned by W. R. Walker to study the causes of the rail failures which were troubling the South Chicago works. He remembered what he had heard about microscopic study of metals and soon succeeded in photographing rail sections, with great benefit in guiding toward modification of manufacturing processes to improve their quality.

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* Only two men ever took it, and the degree of metallurgical engineer was substituted for it in 1885.

Whether the paper, "Observations on the Relations between the Chemical Constitution and the Physical Character of Steel," which W. R. Webster presented at the Reading meeting of the A.I.M.E. in October 1892, was the determining cause I cannot tell, but at any rate when arrangements were made for participation by the Institute in the International Engineering Congress held at the World's Fair in Chicago in August 1893, a group of papers on related topics were arranged for. H. M. Howe presented one on the "Heat Treatment of Steel"; A. Pourcel one on "Segregation and its Consequences in Ingots of Steel and Iron"; Adolph Martens on "Microstructure of Ingot Iron in Cast Ingots"; Floris Osmond on "Microscopic Metallurgy," and Sauveur one on "Microstructure of Steel." The discussion of all these papers, which were treated as a group, was subsequently printed in the A.I.M.E. TRANSACTIONS under the heading "Physics of Steel" (**23**, 608; **24**, 759). It does not seem too much to say that this was the debut of physical metallurgy in the United States, and Sauveur's paper was extremely important, showing how the operating end of the industry could put to practical use techniques developed by research workers. Probably the first definite course of instruction in this subject was the one in micrometallography, which E. D. Campbell was offering at the University of Michigan in 1897.

Henry M. Howe was appointed professor of metallurgy at Columbia School of Mines in July 1897, and both in organizing a junior staff and in attracting graduate students gave much attention to this new viewpoint in metallurgy. Among the graduate students was William Campbell, who came there from the Royal School of Mines as a Royal Exhibition Scholar, took his Ph.D. in 1901, and remained the rest of his life with his major interest in physical metallurgy, eventually becoming Howe professor. When he died in 1936 he left almost his entire estate to endow fellowships for research in metallurgy. Meanwhile Sauveur had left Illinois Steel to open a testing laboratory in Boston; in 1899 he was appointed instructor in metallurgy at Harvard and was made professor in 1905. From these two active centers of microscopic metallurgy others quickly developed. As an example of how far-flung such influences are, the writer may be pardoned for mentioning that he introduced the study of metals under the microscope at Pei Yang University, China, in 1908. Sauveur developed, in 1904, a set of lessons for teaching metallography by mail and throughout his life (he died Jan. 26, 1939) his chief interest was in physical metallurgy, attracting to his laboratories many graduate students. Many other persons might be mentioned as having contributed to this new approach toward metallurgical problems, and it is to be hoped that some day a thorough study of its development may be made. For our purposes, it must suffice to indicate the approximate circumstances and date of this profound and sweeping change in the concept of the field of metallurgy. From that time process metallurgy, which had monopolized attention, dwindled in importance, and physical metallurgy, as it continued to be called, grew apace.

Principles and Practice

Really adequate teaching of process metallurgy in the United States probably dates from the appointment of Heinrich O. Hofman as professor of metallurgy at South Dakota School of Mines in 1887. He had taken both the mining and metallurgical degrees at Clausthal in 1877 and after coming to the United States had engaged in metallurgical practice here from 1881 to 1887. Hofman later went to Massachusetts Institute of Technology, where his instruction was eventually carried on by C. R. Hayward. Egleston, who was the best known teacher of metallurgy from the sixties to the nineties, had never had any real operating experience, but so little was known of the fundamentals of metallurgical operations at the time that the descriptive teaching of how metallurgical operations were carried on was about as much as anybody could do at first. A man who had a wide knowledge of that from observation and reading was probably as effective a teacher as one who had a more intimate knowledge of operations from personal experience, which would necessarily be confined to a narrower field. A knowledge of the why as well as the how of metallurgical operations was gradually being built up by operating men of a scientific turn of mind.

Henry M. Howe succeeded Egleston at Columbia as professor of metallurgy in 1897, as already stated. He had originally been interested in copper metallurgy, and his 107-page "Copper Smelting," published by the U. S. Geological Survey in 1885, was the first separate American text on the subject of which the writer knows, but by the nineties his interests were as indicated above. He had been a special lecturer at Massachusetts Institute of Technology for some time, where Ordway had turned to his interests in chemistry and R. H. Richards had been diverted from his early interest in the metallurgical laboratory to ore-dressing problems. Hofman was called from South Dakota School of Mines to M.I.T. in 1889 as assistant professor of metallurgy and became full professor in 1898. Probably it is not too much to say that he was the first teacher of metallurgy in the United States with both good fundamental training and operating experience.

Edward Dyer Peters, a graduate of Freiberg in 1869, a builder and operator of smelting works in the West between 1869 and 1874, from 1880 to 1884 working in the smelting of copper and nickel, the builder of the Parrot smelter at Butte in 1884, and general manager of the Canadian Copper Co. at Sudbury 1888–90, was appointed professor of metallurgy at Harvard in 1904. He had written a series of articles for the *Engineering and Mining Journal* in 1887, which were issued in book form as "American Methods of Copper Smelting," reissued as "Modern American Methods of Copper Smelting" in 1891, and in a seventh edition as "Modern Copper Smelting" in 1895. In 1907 he published "Principles of Copper Smelting." For the last two years of his life (he died in 1917) he was professor at both M.I.T. and Harvard. A man of science and a great teacher as well as an experienced operating man, he was a notable feature in the teaching of process metallurgy. Arthur L. Walker succeeded Howe as professor of metallurgy at Columbia in 1908. The inventor of the casting machine that bears his name, and of a system for electrolytic copper refining which came into almost universal use, he also brought a wealth of operating experience to his teaching work.

During this period also, both teachers and practitioners of process metallurgy were benefiting from another development. The quantitative approach lies at the heart of progress in design and improvement in all branches of applied science, but for a long time this important side of metallurgy was rather neglected. Not until the work of Joseph W. Richards at Lehigh did metallurgical calculations assume prominence in metallurgical education and as a tool in the laboratory and in industry. Richards graduated from Lehigh in 1886 and his first published work was his treatise on aluminum (1887), based on his undergraduate thesis. The third edition of this book (1896) remained for 29 years the one comprehensive work on aluminum, a position to be remarked on in these days of prolific writing. During this period aluminum was developing from the status of rarity to fifth position among industrial metals. The first part of Richards' "Metallurgical Calculations" was published in book form in 1906. Parts II and III followed later, and in 1918 the three parts were first issued in a single volume. Translations were published in German, Russian and Italian.

Metallurgy was established as a separate curriculum at Lehigh in 1899, with Benjamin W. Frazier, who was professor of mineralogy, as its head. It was under Professor Frazier that Richards received his metallurgical training. Richards became head of the department in 1905. Instruction in physical metallurgy at Lehigh was subordinated to that in process metallurgy until after Richards was succeeded by Bradley Stoughton in 1923. Stoughton, a younger associate and admirer of both Howe and Sauveur, and adjunct professor of metallurgy at Columbia, published his "Metallurgy of Iron and Steel" in 1908. He realized the growth in importance of physical metallurgy and advanced its position accordingly.

Thus it will be seen that, starting as but little more than a description of an ancient practical art in the sixties, metallurgical teaching had by the 1900's advanced, along with the enormous advancement in the art itself, to where principles as well as practice were being taught. Not only that—the field of metallurgy was dividing into two branches; one concerned primarily with the production of metal from the ore, and the other with the quality and usability of the metal thus produced. With the increase of knowledge as to why metals exhibit the characters they do in industrial use, there was developing a science of the study of metals and an art of producing what might be described as tailor-made metals and alloys—metals consciously produced to have the characteristics desired in them, whether hardness, strength, ductility, electric conductivity, corrosion resistance, or any desired combination of these. The adoption of the term "physical metallurgy" to designate this new field was rather unfortunate, obscuring the fact that only the most elementary aspects of physics were involved. Only recently has modern physics begun to be applied to metallurgy.

Geographic and Economic Correlation

At first there had been no correlation between metallurgical instruction and the areas in which it was given. Students in Pennsylvania and Illinois were taught the process metallurgy of gold and silver on the tacit assumption that they would go, after graduation, where it could be usefully applied. Gradually there came to be some adjustment, and schools in the West, where metallurgical operations are chiefly of the process type, concentrated attention on that phase, while schools in the East, where interest in the utilization of metals was more widespread than interest in their production, tended to emphasize their work in metal utilization. The geographic and economic correlation is not perfect, since western schools also find it necessary to teach physical metallurgy, but the trends have been evident.

Metallurgy in Various Departments of Instruction

Meanwhile the chemists had always been interested in metallurgy and inclined to class it as a subheading under chemistry, as the applied chemistry of the metallic elements. Every book on industrial chemistry devotes a good deal of space to metallurgical process, and until the metallurgist began seriously to study the physics of metals, metallurgy was thought of as an industrial art based on chemistry, as indeed most process metallurgy is. The development of the cyanide process for gold and silver and the electrolytic production of aluminum in the late eighties, the rapid expansion of electrolytic copper refining after 1890, the development of the concept of chemical engineering as a department separated from chemistry after 1900, and the remarkable way in which processes and equipment first devised for metallurgical purposes found their way into general industrial chemical uses, all operated to strengthen the ties between chemistry and metallurgy. Every metallurgist must have a sound knowledge of chemistry; every chemical engineer needs to know a good deal about metallurgy.

During the years that instruction in mining and metallurgy was given at the University of Michigan (see p. 60) the metallurgical instruction was given by members of the chemical department. A. B. Prescott (who later became director of the chemical laboratories) had the title of lecturer in metallurgy from 1865 to 1870. He was followed by Silas H. Douglas, professor of metallurgy and chemical technology, and Byron B. Cheever, professor of general chemistry and metallurgy. John W. Langley was professor of general chemistry and metallurgy in 1889–90 and E. D. Campbell was made assistant professor of metallurgy in 1890. The course in micrometallography offered by Campbell after 1897 has already been mentioned as probably the first of its kind in the United States. Chemical engineering was established as a separate department in the College of Engineering in 1898 and took over the metallurgical instruction. This department was renamed "chemical and metallurgical engineering" in 1929 and provision was made for granting the Ph.D. degree in metallurgy. In 1935 a four-year curriculum leading to the B.S. degree in metallurgical engineering was established.

A. E. White is professor of metallurgical engineering and director of the department of engineering research, and William P. Wood and Clair Upthegrove are professors of metallurgical engineering. Lars Thomassen and Richard Schneidewind are associate professors and Clarence A. Siebert is assistant professor of metallurgical engineering. The department offers such courses as engineering materials, fuels and furnaces, utilization of fuels, refractories; crushing, classification, filtration, calcination, and conveying; structure and properties of metals, metallurgical principles of physical metallurgy, metallurgy of iron and steel, nonferrous metallurgy and metallography, X-ray studies, and various advanced courses in this field. During the five-year period ending June 1940, 35 master's and 10 doctor's degrees were given in metallurgy. Thus, although the University of Michigan has no separate department of metallurgy, it has been offering more, and more advanced, instruction in that subject than some institutions that had separate departments. Michigan has an enormous amount of manufacturing industry dependent on metallurgy and apparently the arrangement described was adapted to the needs of the area the institution served.

Metallurgical instruction leading to a degree was revived at Rensselaer Polytechnic Institute in 1932–33, as an outgrowth of the work in electrochemistry. It will be remembered (see p. 69) that Rensselaer had initiated curricula leading to degrees in mining and metallurgical engineering in 1867, but dropped them in 1871. It never completely dropped its interest in them, however. In subsequent years determinative mineralogy and the metallurgy of iron were included in the civil engineering curriculum, and in the 1880 announcement mining engineering was included in the civil engineering curriculum and a six-weeks summer course in assaying was given. A curriculum in natural history leading to the B.S. degree was established in 1885, in which this work was also included. After 1893 a metallurgical excursion was added to the civil engineering curriculum. The instruction in assaying was gradually strengthened to include ore analysis and was made a regular course in the school year in 1902. Enrique Touceda, who had been metallurgist for the Troy Iron and Steel Works, was appointed professor of metallurgy in 1907, to strengthen the instruction in that field. The next year departments of mechanical and electrical engineering were established, and metallurgy was included in their curricula. M. A. Hunter was appointed to the teaching staff in 1908, his special field being electrochemistry, and he developed metallurgical instruction to a point where it seemed wise to carry it further and offer a curriculum leading to the B.S. degree in metallurgical engineering. A department of metallurgical engineering was established in 1932 with Professor Hunter as its head, and Scott Mackay was brought from the University of Wisconsin as professor of ferrous metallurgy. The Institute had an enrollment of 93 students in this curriculum in 1939–40. The emphasis is on the metallurgy of the uses of metals in industry, rather than on the production of metals from ores: This is another example of adjusting curricula to the needs of the time and place, since it was the fact that graduates of the Institute were engaging in employment for which additional metallurgical instruction would have been useful that led to the reestablishing of the metallurgical curriculum.

Purdue is the most recent institution to establish a metallurgical curriculum, leading to a degree, in its chemical engineering department. Purdue University is the land-grant college of Indiana, but takes its name from John Purdue, who with the help of others raised $200,000 and gave 100 acres of land to have it established in Tippecanoe County. Its first president (1872–74) was Richard Owen, who came there from the University of Indiana. Adhering closely to its original aim of offering instruction in agriculture, engineering, applied science, and pharmacy, it early developed curricula in civil, mechanical, and electrical engineering, which grew so rapidly that it has much the largest enrollment of engineering students of any institution in the United States. It did not, however, attempt at first to provide instruction specifically directed toward the mineral industries. It established a School of Chemical Engineering in 1911 and, as at Rensselaer, the metallurgical instruction given in this department gradually developed until it seemed desirable to introduce a curriculum leading to the degree of bachelor of science in metallurgical engineering. J. L. Bray (S.B. M.I.T., 1912; Ph.D., 1930), who had been appointed professor of metallurgy in 1925, was made head of the School of

Chemical and Metallurgical Engineering in 1935. He is assisted by four other staff members in metallurgical engineering. The curriculum leading to the degree in metallurgical engineering was first offered in 1938 and the enrollment in it for the session 1939–40 amounted to 34 sophomores and 24 juniors. It is interesting to note that the instruction in crystallography, mineralogy and geology at Purdue is given in the School of Chemical and Metallurgical Engineering.

The number of institutions at which some instruction in metallurgy is given in either the chemistry or chemical engineering department is too great for mention of their names. The work at Princeton has been mentioned (p. 208) and how the metallography and X-ray work which developed in the chemical engineering and physics departments, respectively, at M.I.T. has recently been transferred to the metallurgy department was told on p. 175. What is perhaps less generally known is that in some institutions metallurgical instruction is offered by the mechanical engineering department. The basic reason for this is that if in the academic setup of an individual institution there is no provision for adequate instruction of engineering students in the nature and characteristics of metallurgical engineering materials the mechanical department must itself provide for it. This may be done either by bringing in outside lecturers or appointing as instructor in the department someone who has had metallurgical training. The casting, rolling, forging and drawing of metals are processes that need to be studied both by metallurgists and mechanical engineers and relatively few metallurgical departments are equipped to handle them from the mechanical side, while mechanical engineering departments are seldom prepared to handle the metallurgical problems involved. It seems possible that in future years a joint field of mechanical metallurgy may develop; meanwhile the teaching of metallurgy to mechanical as well as chemical and electrical engineering students has become a vocational opportunity for metallurgical engineers.

Research Laboratories

Another interesting feature of the present situation in education for the metallurgical industry is that the large research laboratories established by the larger metallurgical enterprises employ the services of large numbers of chemical engineers and chemists, a smaller number of physicists, and relatively few metallurgists. The reason for this is obvious; metallurgical problems when broken down into their elements have to be attacked by chemical and physical methods of study, and after the directing metallurgist has outlined the problem and reconnoitered possible means of attack the actual laboratory work can be done by men who have specialized in laboratory work in pure science. In the conduct of these investigations they gradually acquire much metallurgical knowledge. It was pointed out in the preceding chapter that it is beginning to be claimed that the production of metals from their ores is one phase of mineral dressing, so that metallurgists are beginning to be hemmed in by chemists and chemical engineers on one side, physicists and mechanical engineers on another, and by the new type of mineral dresser on a third, with the result that there seems almost no area left which is the peculiar possession of the metallurgist. One would need to be a prophet to foresee what the eventual outcome of this situation will be, but one fact is evident—the number of students registering in metallurgical curricula has for some time been increasing, and that trend bids fair to continue.

Mining

It is not necessary to repeat that the original concept of a mining education was that it covered all the applications of scientific knowledge to the problems involved in finding minerals, getting them out of the ground, and converting them to the specific uses for which they are suited, since preceding chapters have traced the way in which the sum of knowledge available on each phase of this sequence of operations has increased, until it is large enough to constitute a separate curriculum by itself. Mining now signifies, in a narrow sense, the taking of minerals out of the ground and putting them where subsequent processes may be applied to them. Coal mining remains much the same operation it always was, except for the increasing substitution of mechanical energy for human effort, which means working on a larger scale, developing new devices and equipment, and the use of safer explosives. In metal mining, on the other hand, there has been at least one fundamental technical change, the introduction of block caving as a system of mining. Though this, from an engineering standpoint, is basically different from the systems previously used, it was not developed as a result of any engineering discoveries or analysis, but was an empirical development from the established art. Much has been said about the increased production of minerals by surface (open-pit or strip) mining methods, but when the actual records are studied we see that surface mining of bituminous coal has increased only to where a little over 7 per cent of the 1937 output was produced by that method, and about 12 per cent of anthracite was similarly mined the same year. About half the iron ore produced in 1938 was obtained from surface operations, but that does not represent any material change in a relationship which existed 30 years earlier. Only in regard to copper ore has there been any material change in the relative proportions—about 5 per cent in 1908 and nearly 40 per cent in 1938—but even that does not represent any basic technical change. The recent trend toward the use of belt conveyors and trucks instead of railroad cars as a means of getting the ore out of the pits is merely the substitution of improved types of equipment for older ones, rather than any basic change in engineering practice. The concentration of mining operations resulting from the use of large mechanically powered units, as contrasted to hand-power mining, presents a superficial appearance of great change, but it is only a quantitative change; while the block caving presented an opportunity and need for special study of the mechanics of materials involved in the operation.

Thus we have had in mining education a persistence in the original function of the school of merely informing its students concerning good practice in the practical art. This has not been true of electrical engineering and mechanical engineering, where laboratory research and the attainment of a better understanding of fundamental principles has reacted to affect profoundly industrial procedures, which thus have been transformed from practical arts to applied sciences. Of recent years much of this progress has stemmed from great research laboratories, such as those at Schenectady and Pittsburgh, but it was initiated in educational institutions, which remain great and important centers of basic research. The mining schools, on the other hand, had never attempted, until recently, to initiate any fundamental studies of mining engineering, as distinguished from mechanical engineering applied to mining operations, nor do the few large operating companies that have a research unit in their operating staff attempt to do more than make accurate comparative tests of the results attained by alternative methods of operation. We will return to this topic in a moment.

Meanwhile the increase in size of mining operations and the changes in practice mentioned above had reacted to produce an immense increase in the importance of factors in the total operation of mineral production that had been largely overlooked in early days. Consideration for the health and safety of the workers, improved working conditions, higher wages, employer-employee relations, increasing government control, and above all the problems of marketing minerals, especially those which are competitive with each other, became quite, or at times even more, important than the finding, breaking, and hoisting of mineral. It is not clear whether an appreciation of this fact had any importance in leading to the decision of a few schools to put their mining instruction on a graduate basis, but it seems unlikely, since where that was done the emphasis placed on the necessity of a broader general education underlying technical instruction seems to have stemmed from a somewhat blind faith in the general cultural values of "humanities" rather than from any clear appreciation of how a broad general education might serve to better prepare young men to assume all the responsibilities connected with mineral production. College instruction in history and the elements of classical economics has a value in preparing a mining student to acquire a grasp of the problems mentioned above, but does not of itself impart that grasp.

Modifications in Courses at Columbia

When the author took up his duties at the Columbia School of Mines in 1929, he and his colleague, Prof. Philip B. Bucky, then assistant professor of mining, who joined the staff at the same time, considered at great length the matters set forth above, coming to the conclusion that the traditional mining courses included in the mining curriculum needed modification in two directions. The first was that the time allotted to consideration of the problems of mine management needed to be increased, and that the subject matter needed to be changed so as to deal more directly and effectively with matters likely to come within the range of experience of a young engineer shortly after graduation. A new course, mineral economics, was introduced to permit a broad treatment of the economic problems of the mineral industry, with special emphasis on the marketing of minerals and the relationship of mineral production to society as a whole, notably as regards transportation and taxation. Instruction in safety, management of labor, and the general conduct of mineral enterprise was enriched, part of the needed time being gained by reducing the time formerly allotted to description of mining methods and changing its subject matter to a discussion of general principles illustrated by type cases. Discussion of the mechanical equipment used in mining was based more completely on previous mechanical and electrical instruction and its treatment made more critical.

This first was not difficult to do, since the content of such instruction was already available, the problem being one of proper presentation. The second modification required—to base mining instruction more definitely on engineering principles—as contrasted to the application of good engineering practice to mining operations, presented much greater difficulty because that approach had not been developed. To such engineering questions as: What is the safe span of a room or stope? What dimensions and shapes shall pillars be made? What length of face shall be used in longwall? Will ore block-cave? What development work is required to produce block caving? How long a time will be required? and many others, no theoretical response could be made, because the engineering analysis of them had not been made. Similar questions regarding structures built on the surface can be answered because the mechanics of materials that are isotropic and are stressed within their elastic limits has long been understood, while engineers have tested to destruction, either on full scale or as models, the actual materials of construction, none of which are perfectly isotropic. Full-scale tests on mine structures seemed out of the question, because of the expense, danger, and length of time required, and no practicable method of testing models was known, since the forces to be dealt with were those of gravitation, which could only be developed on a full scale.

At this point Professor Bucky perceived that the general law of similitude, that a scalar model made up of the same material as its prototype will behave like its prototype if the model weight is increased in the same proportion as its size is decreased, applies to mine structures, and that a centrifuge offers a practicable means of increasing the weight of the model proportionately to its decrease in size. This opened the door to the making of tests on mine structures and as soon as the preliminary work of devising the necessary equipment and learning the techniques of its use had been done they were begun. The results of this work have been reported in a series of papers published in the TRANSACTIONS of the American Institute of Mining and Metallurgical Engineers, and elsewhere, and need not be recorded here. More recently the correlation of the laboratory tests with field observations has been undertaken, with surprisingly good results. The next step was to incorporate these new concepts into the teaching of mining methods, which is now in progress. Once this new approach to the engineering problems of mining is fully accepted, no great difficulty need be experienced in reorganizing mining engineering instruction on the new basis. It is clear, however, that it offers the only effective answer to Wellington's strictures on mining engineering education, quoted on p. 128, and to the views of C. C. Williams, now president of Lehigh University but then dean of engineering at Iowa State University, who said[66] in 1934 that "In general it may be said that, for the most part, mining engineering is an assembly of rather elementary operations in the other branches of engineering, and with the growth of large mine-owning corporations, which have been inclined to pool their engineering operations, the field for the mining engineer has tended greatly to decrease."

The fundamental error of those who believe that mining engineering is merely as "assembly" of other engineering techniques is not the failure to realize that it has an engineering content peculiarly its own, but in believing that engineering techniques can be "assembled" by having a number of men, each of whom knows one, work together. An example from the author's experience may serve to make this point clear. Faced with the task of making a motion picture to show safe methods of coal mining, it was easy to secure a man expert in coal mining and another equally expert in making motion pictures, to work together on its production. The results were lamentable, because the coal man knew nothing of motion-picture making and the picture man knew nothing about coal mining; to direct the picture required someone who understood both. No engineer other than a mining engineer knows enough about geology, especially structural and economic geology, to direct mining operations, and if, through experience in the mineral industry he has acquired that ability he has become a mining engineer, even though his school training was in some other field of engineering. If there were no schools to train mining engineers they would continue to be developed in the school of experience, but it must be evident that if there is no need for the special training of mining engineers neither is there any for the special training of mechanical and electrical engineers, and we should count on the needed special types developing out of a single curriculum in general engineering.

Transfer Value of Mining Curriculum

Since instruction in mining engineering has remained more generalized than other types of engineering instruction, graduates of mining curricula have been more prone to engage in work other than that for which they specifically prepared. The mining curriculum apparently has a larger transfer value than most other engineering curricula. Though this is an advantage, it has reacted to create the impression that mining engineering as a career is not attractive, because so many men who have trained for it do not follow it. The real criterion, to the author's way of thinking, is the employment value of a special curriculum —a mining company would not be likely to hire a ceramics engineering graduate, not because of unawareness that his special training was based on a good general engineering foundation, but because his selection of that curriculum indicates that his main interests do not coincide with those of the company. Actually the choice of a curriculum often involves many other things than major interest, such as response to family wishes, desire to continue to work with a "buddy," the local reputation of the department, and others too numerous to mention, including pure chance. Some young men take a job with a big organization and thereafter develop according to its needs rather than their own desires; others deliberately change if they consider they are not developing according to preconceived notions, while still others get jobs that do not last long and have to seek new connections at frequent intervals. The general problem is so individual in actual fact that it does not seem possible to generalize about it. There are more employment opportunities for chemical, mechanical, and electrical engineers than there are for mining engineers, and even though there are more applicants for such positions it is more likely that a young man seeking reemployment will be able to get back into the same field in which he has been working.

Localization of Education and Employment

It must not be forgotten that both education and employment are much more localized than is commonly recognized. Even the most widely known institutions draw much the largest proportion of their students from within a circle with a radius of 100 miles, and their graduates mostly find employment within the same area. The growth of registration in petroleum curricula in states where petroleum is the principal industry clearly reflects this correlation. It is to be expected that mining curricula will flourish best in institutions that are in areas where there is employment for mining engineers. That includes the business as well as the practice of mining; London and New York are great centers for mining engineers.

From this it follows that there are relatively few areas in the United States where there is any necessity for a separate School of Mines, which must maintain facilities for instruction in mathematics, physics, chemistry, civil, mechanical, and electrical engineering courses that in a large general institution can be given by the corresponding departments. The Colorado and Montana Schools of Mines are the only two institutions that offer only mineral industry education. The South Dakota, Michigan, and Texas (El Paso) schools are separate institutions, which have broadened their fields to meet their local needs, but the greater part of mineral industry instruction is offered by large institutions which cover the whole educational field, and its relative importance in the institution is chiefly a reflection of the relative importance of mineral enterprise in the area served by the institution. In the beginning mineral industry instruction was chiefly offered by private educational institutions; now it is chiefly offered in connection with State universities.

As an example of this trend, the recent development of public mineral industry instruction in the state, which, next to Texas, has the greatest value of annual output of mineral products may be cited. The early history of Pennsylvania State College was given in chapter 9. Since 1927 both its student body and physical plant have been more than doubled in size. The enrollment of regular full-time students has increased from 3500 to 7200, and 26 new campus buildings have been provided, at a construction cost of $11,250,000, the latest 5,000,000 project having been financed both by the general State authority and the Public Works Administration.

In 1929 the plan of organization of the School of Mines of the College was changed and it was renamed the School of Mineral Industries. A curriculum in petroleum and natural gas engineering was added in 1930, with Dr. S. J. Pirson in charge, and one in fuel technology,* 1932, with Dr. A. W. Gauger as head. Dr. N. W. Taylor succeeded Professor Shaw in 1933. Prof. D. R. Mitchell, head of the Mining Department, succeeded Prof. W. R. Chedsey, who accepted the directorship of the Missouri School of Mines and Metallurgy in 1937. A Division of Geography was organized in 1932, a Division of Geophysics and Meteorology in 1933, and a Division of Mineral Economics in 1938. The School now offers six curricula leading to the B.S. degree in: (1) mining engineering, (2) metallurgy, (3) earth sciences, (4) ceramics, (5) petroleum and natural gas engineering, and (6) fuel technology. The total enrollment in these curricula in 1939–40 was 309, distributed as follows: Mining Engineering 35, Metallurgy 126, Geology 25, Ceramics 39, Petroleum and Natural Gas

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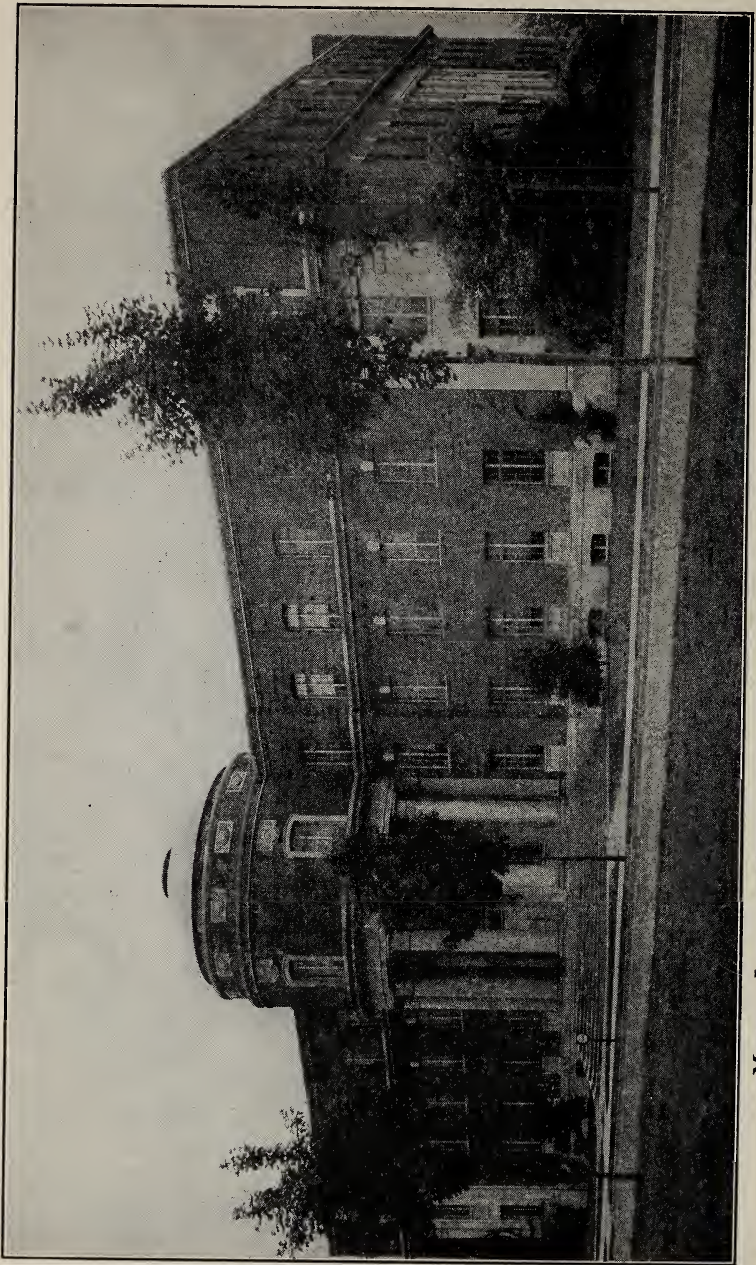
* This is the only curriculum leading to a degree in fuel technology offered in the United States. Colorado School of Mines offers a fuel option in the third and fourth years of its mining engineering curriculum.



Mineral Industries Building, The Pennsylvania State College. Erected in 1931.

Engineering 62, and Fuel Technology 22. In addition, there were 25 graduate students, distributed as follows: Mining Engineering, 1, Metallurgy 3, Geology 2, Ceramics 8, Petroleum and Natural Gas Engineering 6, and Fuel Technology 5. The School of Mineral Industries gives "service courses" to 2000 students enrolled in other schools on the campus. There are 1054 graduates of the School from curricula leading to a degree.

In common with all other eastern schools offering instruction for the mineral industries, enrollment in the mining curriculum at Penn State has tended to decline of recent years, and metallurgy to increase, the growth of interest in the other curricula having apparently been mainly at the expense of mining. The following has been furnished by Dean Edward Steidle:

> The School has an extensive research program under an Experiment Station plan, much of which is supported by industry. The Experiment Station was organized in 1919, although the results of approved research on Pennsylvania clays and building stones were published in bulletin form 1896–99. All members of the faculty participate in research; there were 42 approved projects in 1939–40. The Experiment Station has published 32 bulletins, 61 technical papers and 11 information circulars. Members of the faculty have published 2 monographs and 6 textbooks. Annual industrial conferences and research meetings have been made an integral part of the program. Dr. Gauger is director of research.
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> A notable feature of the work at Penn State is the large scale on which it carries out extension work of noncollege credit throughout the state. In 1939–40, 3964 students were registered in 173 classes in 99 class centers in 34 counties in the state. The School is a pioneer in mineral industries extension instruction, mining extension dating back to 1893. The Division of Extension was organized in 1919 and has published 15 textbooks, while 3 additional texts on fuel technology are in manuscript form. H. B. Northrup is director of the division.
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> In 1939–40 there were 51 regular members of the resident faculty, 1 technical librarian, 1 analyst, 1 stock clerk and 3 instrumentmakers. Forty-six American universities and 16 foreign universities were represented. Thirty-two members had Ph.D degrees and all had M.S. or equivalent degrees. A majority of the members had excellent industrial experience.

University of Alaska

The University of Alaska, College, Alaska, is the latest institution to offer a curriculum in mining engineering. The institution was authorized in 1915 by Congress, which granted a considerable area of land in the Tanana Valley for the support of any territorial college and school of mines, and 2210 acres of land 3 miles west of Fairbanks as a site for it. In 1917 the legislature incorporated the Alaska Agricultural College and School of Mines and appropriated $60,000 to provide buildings. As this sum proved inadequate, an additional $41,000 was appropriated in 1921. Charles E. Bunnell was elected president of the College and it began work on Sept. 18, 1922. In 1935 its name was changed to the University of Alaska. It is a coeducational institution offering four-year curricula leading to the bachelor's degree in agriculture, arts and letters, business administration, chemistry, civil engineering, education, general science, home economics, and pre-medical. There is also a five-year curriculum leading to the degree of bachelor of civil engineering. In the School of Mines there are four-year curricula leading to the B.S. degree, and five-year curricula leading to the degree of bachelor of mining engineering, metallurgical engineering, and of geology and mining, respectively.

Ernest N. Patty was made head of the School of Mines and professor of geology in 1922, E. R. Pilgrim was professor of mining and metallurgy; seven students were enrolled in the School of Mines that year. J. H. Hance, who had been dean of the School of Mines in Oregon, succeeded Patty in 1935 and was in turn succeeded by Raymond J. Barber in 1937. Livingston Wright became assistant professor of mining and R. C. Ragle instructor in metallurgy in 1938. For obvious reasons there is much interest in the mineral industry curricula. Between 1922 and 1935 the University had granted a total of 96 degrees in course; 35 degrees had been granted in the School of Mines to the end of 1938, and there were 77 enrolled students in 1938–39.

In addition to the work described short courses in mineralogy, geology, mining and assaying are given yearly for prospectors, with an average attendance of about 20. A special appropriation in 1935 provided for extension work in southeastern Alaska and during the first three years 1679 students were enrolled in five-week courses given at various centers of mining interest. A second instructor was provided for this work in 1938 with the intention of extending the work to 12 centers.

Field for Mining Engineers

To summarize what has been said, metallurgical instruction was at first typically included in a single comprehensive mining curriculum. The first broadening and deepening of the content of the field of metallurgical knowledge was in process metallurgy, but 50 years ago it began to embrace the study of metals in their commercial applications, a field that has come to overshadow the first. The mining curriculum at first attempted to cover all the applications of chemistry, geology and general engineering to mineral production and utilization problems; it continued to attempt to do this long after the necessity for it had passed. The effective correlation of these related fields must be done through proper academic organization, which is discussed in detail in the concluding chapter. The concept of development of a field for mining engineers which is peculiarly their own is hardly more than a decade old, but is surely destined to persist and expand, since the problems of mining ore deposits at great depth will involve advanced knowledge, and assemblages of fields of knowledge, which graduates of other engineering curricula do not possess.

Chapter 14

SUBCOLLEGIATE AND VOCATIONAL EDUCATION

IT will be recalled that when educational instruction for the mineral industry began at Freiberg, at the beginning of the eighteenth century, the original aim was to organize and systematize the procedures previously followed by young men in gaining familiarity with the technology then in use. There must have been many other ideas current, even then, as to just what a young man needed to learn in order to become capable of assuming responsibility for the supervision and direction of such technical work. The problem in Europe was decidedly different from that in nineteenth-century America, because some of the European mines were actually owned and operated by the governing authority and the others were supervised, regulated, and taxed by it. The American problem was the efficient performance of technical operations; the European one was regulatory supervision.

It was natural, therefore, that in the development of educational processes in Europe stress was laid on those factors which conserved and protected the interests of the state. The study of mineralogy and geology, leading to correct judgments as to the workability and value of mineral deposits; assaying, which gave the means of quantitative measurements, as did surveying; chemistry, which furnished a better basis of understanding for assaying, mineralogy, and geology; and physics and mathematics, which are the bases for the understanding and efficient use of mechanical appliances, became the core of systematic instruction for the mineral industry. It was early recognized that men could learn more than was already known about all of these subjects and education took on that dichotomy which still characterizes it; the teaching of established knowledge to the unlearned, and that of extending of the bounds of knowledge, now loosely termed research, which after two and a half centuries of work still shows no signs of approaching its ultimate limit. Freiberg was long one of the best places in the world for the advanced study of mineralogy, geology, and chemistry, though it had had its origin in an aim to provide instruction in the actual conduct of mining and metallurgical operations.

It must early have been clear that these operations are, to a large degree, practical skills, and the social setup of the time was such that a worker, as a rule, never expected to be anything beyond a skilled worker. Educational procedures did not at first aim at the development of the individual.* It must have been observed, quite early, that there are considerable differences between workers in degree of skill, and the inference would be drawn that it was worth while to "educate" workers. It was not a clearly defined policy, for the idea long held sway that a worker must educate himself in order to get and hold a job. However, wherever and whenever a labor shortage existed it must have been evident that output could be increased by increasing the efficiency of the workers, as well as by putting more of them at work.

Without delaying to discuss these complicated matters in more detail it must be enough to remark that it was natural for education for the mineral industries to divide into two branches, which might be designated as the manual and the mental, something like the distinction between muscles and nerves. The latter was again divided, as noted above, into two branches, research and the application of knowledge to productive operations. The former may also be thought of as dividing into two branches, the training of a worker to do a specific task better, and giving him some general education in the belief that he will thereby be enabled (*a*) to develop himself or (*b*) improve his work in accessory ways. An example of the last is the teaching of English to foreign-born workers so that they can understand directions and orders better, while the teaching of elementary mathematics and other cultural subjects is expected to promote personal development. But these matters are complicated, since the result of giving drawing instruction may be that a person who already can draw will learn to do it better, while another who did not know how to draw might either thereby qualify for a better job than he had, or might become a more contented worker at his present job through acquiring another interest and a feeling of personal progress.

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* Bacon, Rathke, and Comenius were seventeenth-century pioneers of the concept of education for individual development, but it was not until the time of Pestalozzi, Hebart and Froebel that it was widely accepted.

Since there is no sharp dividing line between workers and administrators in modern industry, and in some fields, notably railroad transportation, the highest officials are supposed to attain their positions by gradual development, beginning with the simplest tasks, there should be no dividing line between the education of workers at its highest level and the education of officials. Practically there is a distinct line, as has been pointed out in a preceding chapter, since the education of workers is typically only collateral to the earning of their livings, whereas youths seeking to qualify for official positions typically devote their whole time, until reaching the age of 21 or 22 years, to the acquiring of a preliminary education at a high level. Whether acquiring education is a full-time or a part-time activity makes a profound difference in its organization and conduct. (It is taken for granted that everyone, including the youth himself, realizes that his education is not completed at the age of 22, but that he is until then merely making a full-time job of theoretical education preliminary to engaging in self-supporting work, after which continued education can be only collateral.)

Subcollegiate Work

It therefore comes about that we find, in the United States, over 50 institutions of collegiate or university grade offering full-time education at that level for the mineral industries.* Simultaneously a great variety of agencies offer instruction ranging from arithmetic and English up to fairly advanced technology to persons employed in the mineral industries. Some of these are institutions which also offer instruction at the collegiate level, but this subcollegiate work is mostly done by other agencies. It has not been possible, in the time available, to make such a study of these agencies as would qualify the writer to attempt their discussion in as much detail as has been done with education at the collegiate level, but it seems advisable to touch briefly upon them, in recognition of their importance in the general field of education for the mineral industries.

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* Employed persons who have taken a bachelor's degree frequently, where circumstances permit, carry on part-time work for the master's and doctor's degrees in such institutions. See *Coal Age*, April 1941, for discussions of post-graduate practical training.

Wisconsin Institute of Technology

Before the general discussion, reference must be made to the only institution in the United States that while offering mineral industry education of subcollegiate grade* does it on a full-time basis. This is the Wisconsin Institute of Technology, Platteville, Wis., established in 1907 as the Wisconsin Mining School. Two different stories are told as to the circumstances attending the establishment of this school. One is that with the development of the lead-zinc mining industry in that part of Wisconsin an impulse to establish a mining school of the ordinary type was generated. When support was sought for the project in the state legislature the supporters of the University foresaw that it might become to some degree a rival institution and had the Act establishing the School so phrased as to provide only for a State "Mining Trade School" with a two-year curriculum not leading to a degree. The other story is that those who were locally supporting the project never intended it to be anything more than an institution of subcollegiate grade. It is not necessary for our purposes to establish which version is correct† (the more so since it seems altogether likely that there may have existed a difference of views among the supporters of the project), the point being that it was established and still remains the only institution of its special kind in the United States. Under its new charter it will probably gradually develop into an ordinary engineering school with curricula leading to the B.S. degree.

The school, which still occupies the large stone building originally provided for it, admits two classes of students—those who have graduated from high school, and those who have not. Unless the latter have had one year's high school work they are required to pass an entrance examination in arithmetic and English. For the high-school graduates a two-year curriculum is provided, which takes them through qualitative analysis in chemistry, electricity, light, and sound in physics, two terms of calculus, drawing, plane and mine surveying, courses in mineralogy, petrology, and geology, and two terms of mining methods. At the end of this they are expected to transfer to other institutions to complete the work for a bachelor's degree, though one might imagine this might present some practical difficulty, since they have already covered topics that usually appear in the third and fourth years of a four-year curriculum, and have not had all the subjects of the usual first two years. It is not, therefore, a junior college, since this two-year curriculum is not keyed to a four-year one.

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* For vocational schools in Texas and Nevada see pp. 252 and 254.

† Mining and metallurgical instruction at the University of Wisconsin, which had been dropped about 1890, was revived in 1908. See pp. 72–74 and 161.

For students who have not had high-school work a three-year curriculum is provided, leading to a certificate of graduation. The mathematics of this curriculum begins with plane geometry and extends only through trigonometry, but the first two years are otherwise the same as the curriculum just described. In the third year such subjects as strength of materials, mechanical engineering of power plants, structural design, economic geology, quantitative analysis and assaying, and mine valuation and accounting are included. Since its establishment in 1907 it has awarded 350 graduation certificates, of which 9 were given in 1939. In recent years about half the graduates have gone to Missouri School of Mines to continue their work. Its original name of Mining Trade School was first changed to Wisconsin Mining School and, in 1939, to Wisconsin Institute of Technology, with such changes in its act of incorporation as to provide for general engineering instruction and three-year and four-year curricula. It is governed by three Regents, two from the mining district of the state and the third the State Superintendent of Public Instruction. It is wholly supported by State appropriations, but is authorized to charge a tuition fee for nonresidents of the State.

Freeland Institute

In the section on experience in vocational mining education which forms part two of A. C. Callen's bulletin of the Federal Board for Vocational Education on general mining[9] (see also Stoek[60]) the Freeland Mining and Mechanical Institute is grouped together with the Wisconsin Mining School, as two examples of industrial schools. Though possibly similar in their original purposes they developed along quite different lines. Eckley B. Coxe, who was always keenly interested in the welfare of coal-mine workers, started an evening school for men and boys, who were employed during the day, in his own home at Drifton in May 1879. Later in the year it was transferred to a frame building that had been constructed by the Coxe family as a meeting center for employees, and a full-time instructor was engaged. This building burned down in 1888 and, after an interim, a charter was obtained from the State in 1894 for the "Mining and Mechanical Institute of the Anthracite Coal Region of Pennsylvania," to be established in Freeland (about a mile from Drifton). Day classes were started and in 1903 a building was constructed for the Institute. Mr. Coxe died in May 1895, but his widow and friends continued to give* the school financial support, since its original tuition fee of 50 cents per month for an average attendance of 12 did not provide much income. Elementary mathematics, physics, chemistry, drawing, and safety were the principal subjects taught, but many men were prepared for examinations for positions as assistant mine foreman, mine foreman, and mine inspector as well as for entrance to ordinary technical institutions. There were then no entrance requirements. A college-preparatory day curriculum was added in 1901. The night work gradually declined, there having been no mining students since 1926, and no night instruction of any kind since 1938–39. Thus it has now become a college-preparatory school, with two-thirds of its operating expenses provided from endowments, the tuition fee now being $60 per year.

West Virginia Institute of Technology

West Virginia Institute of Technology, which was established in 1895 as New River State College, at first functioned as a preparatory branch of West Virginia University and a proposed trade school but became a junior college. It was given authority to grant the A.B. degree in 1928 and in 1934 introduced curricula leading to the B.S. degree. In 1938, with the cooperation of the Kanawha Valley Mining Institute, it introduced the cooperative system in education, which was originated in 1906 at the University of Cincinnati. The students are selected by mining firms, subject to the approval of the institution, and are divided into two groups, one of which is studying while the other is at work at the mines. These groups change shift every two weeks, and work eleven months of the year for five years. While at work at the mines the students are paid the wage scale prevailing for the task in which they may be employed. So far as practicable, the instruction work at the school is arranged to prepare the student for the mining work to which he will next be assigned. This covers drawing, surveying, mining, mining methods, coal mining, mine ventilation, and mine design. The institution changed its name to West Virginia Institute of Technology in 1941.

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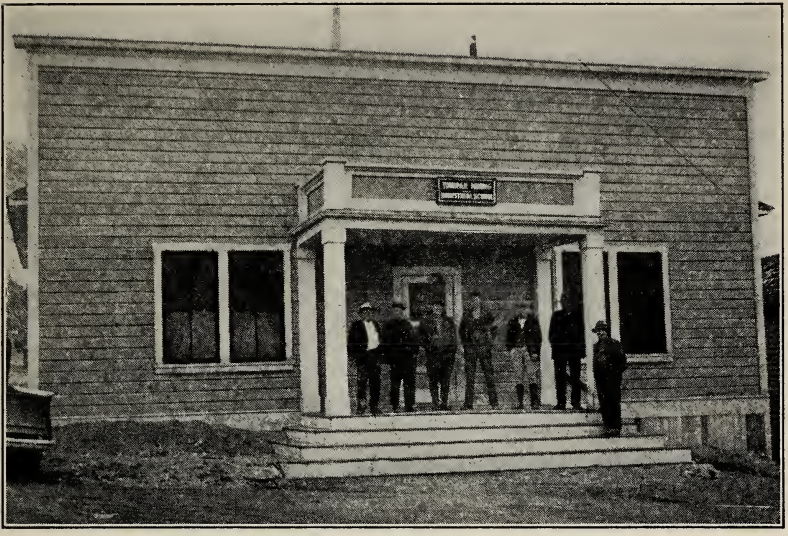
* Eckley B. Coxe, Jr., bequeathed it $25,000 on his death in 1916; Mrs. E. B. Coxe, Sr., provided some endowment funds before her death in 1926.

Tonopah and Ely, Nevada

Two vocational institutions which need more adequate description are those at Tonopah and Ely, Nevada. Reference has been made (p. 103) to the Act of the Nevada Legislature creating a School of Mines at Virginia City in 1903, and what came of it. In March 1915, the legislature authorized a School of Mines at Tonopah and two years later similar schools were authorized at Goldfield and Ely. The one at Goldfield has gone out of existence but those at Tonopah and Ely have developed into vocational schools of an unusual type. That at Tonopah is under the direction of Otis D. Welsch, a graduate of the School of Mines at Pullman, Washington. It is a free school, supported by the Nevada State Board of Vocational Education. There are no entrance requirements and no regular classes, the building provided for it being more or less of a "culture center," to which individuals can come when not otherwise employed and pursue studies of the vocational type under individual guidance from the director. Instruction in fire assaying is most sought after, followed by elementary geology, mineralogy, prospecting, milling and metallurgical recovery processes. The students range in age from 16 to 70, and among the thousand or more who have pursued studies there in its quarter-century of existence have been several women claim-owners. The school at Ely, which is under the direction of Walter W. Anderson, a graduate of the University of Nevada, who was at one time State Superintendent of Schools, is of generally similar character. That these schools are adapted to their environment is indicated by their having continued over so long a period. That similar schools have not developed elsewhere seems to indicate that they are practicable only in an area where the mineral industry is the principal one.



TONOPAH MINING AND INDUSTRIAL SCHOOL.

Sacramento Junior College

Sacramento Junior College, Sacramento, Calif., established a department of mining in the autumn of 1936, under the direction of Waldemar F. Dietrich (E. M. Stanford, 1914), who was on the staff of the mining department at Stanford from 1916 to 1930, becoming professor of mining in 1929. The instruction offered is of two kinds. One course covers the first two years of a typical four-year mining-engineering curriculum; this program being sufficiently flexible so that if the student knows in advance what school he intends to transfer to for the next two years he may prepare directly for it. The other is a two-year curriculum which has for its aim training junior engineers, technicians, mechanics, and other workers for whom two years preparation may be enough. Examples of these are sampler, assayer, mine surveyor, shift boss, and foreman. The courses offered in this field include the elements of mining and metallurgy, fire assaying, wet assaying, surveying, drafting, ore testing, and related work in mathematics, physics, chemistry, and geology.

Kilgore College

The latest development in the vocational field is the work being offered by Kilgore College, Kilgore, Texas. This is a public junior college, established in 1935 as a part of the Texas public school system. Early in 1940 the authorities made a survey of the region (it is in the East Texas oil field) to ascertain what could be done to render more effective educational service in its territory. The conclusion was reached that there were a number of high-school graduates who were not in a position to continue their education, but were also too young and inexperienced to obtain employment. After interviews with some two hundred employers in the district, a cooperative arrangement with the Trade and Industry division of the Texas Board for Vocational Education was devised. The plan provides for high-school graduates between the ages of 18 and 25 to receive instruction in the morning and to work a minimum of 20 hours per week at some occupation in the petroleum or related industries. Two men are to work with such students, one to give the instruction in the school germane to the work the student is doing at other times, and the second to work with employers so as to plan school work to supplement the employment. Both of these men are experienced in the petroleum industry. The wages paid by the employer during the training period will be nominal and at least 20 hours a week of employment will be provided. An advisory committee and craft committees have been created to supervise this work. It will be necessary to wait until this arrangement has been in operation for a reasonable time before attempting to assess its merits, but it is a most commendable educational experiment.

Kinds of Instruction

The various kinds of subcollegiate instruction for the mineral industries are classified by Callen[9] on the following basis:

1. Night schools.
2. Lecture courses.
3. Correspondence courses.
4. Short courses in mining colleges.
5. Industrial mining schools.
6. Underground schools.

The two institutions he lists as industrial schools have been described in the preceding pages. Callen's discussion of the others was largely a bringing up to 1919 of the work in these fields described in Stoek's bulletin,[60] issued in 1914. Since the latter is probably no longer easily available to educators, no apology need be made for again presenting, in abridged form, their main features, and describing the work of the Federal Advisory Board for Vocational Education (now a part of the Federal Security Agency) and of the U. S. Bureau of Mines, which were not covered by either of the previous writers.

Short courses given by mineral industry schools of collegiate grade to prospectors, and other interested persons, have usually been mentioned in connection with the schools where they are given, and nothing further need be said of them here, beyond noting that they should not be confused with courses given in extension by the same institutions. Short courses are given at the institution itself, usually by its regular staff as an extra activity, and in many places only at such intervals as produce a new group interested in such work; extension courses are regular courses given away from the institution, usually by one or more instructors especially engaged for that purpose, at some place where it is convenient for a group to gather in the evening. Extension courses given by institutions of collegiate grade are included in Callen's classification of night schools, and usually they have been mentioned in previous chapters in connection with their respective schools. As an example, the mining extension work of West Virginia University may be cited. It is conducted by nine full-time and several part-time instructors throughout the state, and 2000 to 2200 students are enrolled each year. It was started in 1913 with three short-course students, but when night classes were begun in 1915 the enrollment was 220 the first year and 1806 the next. This work is of noncollege credit grade and is designed primarily for working men at the mines. All of the extension work is in the Mining and Industrial Extension Department of the School of Mines, and provides a valuable and constant contact with the mining industry of the state. (See also pp. 158 and 192.)

The State Manual Training Normal School of Kansas, which does not offer ordinary mineral industry instruction, needs to be mentioned here, however. This school is at Pittsburgh, Kansas, and being in a coal-mining region and nearer the zinc-mining district than the State School of Mines at Lawrence, began offering evening courses for coal miners in 1917. The courses, two hours for one evening each week, were given by the teacher of physics and chemistry in the Normal School. An elementary course deals with mine ventilation, and an advanced course covers explosives, blasting, timbering, and the causes of mine explosions and the need for ventilation.

In other localities the evening courses for miners are usually given under the auspices of the mining companies themselves, or by the local Y.M.C.A., with or without the support of the mining companies. Y.M.C.A. evening instruction for the mineral industries is especially well developed in eastern Pennsylvania. At Wilkes-Barre, Pittston, and Scranton, in the Anthracite district, two-hour classes, meeting two or three times a week for 20 to 25 weeks during the year, are offered for a fee that ranges from $8 to $14 per year. The school at Wilkes-Barre offers a graded sequence of a preparatory year and three years thereafter, using as texts the instructional pamphlets of the International Correspondence Schools, and for instructors technical employees of the mining companies. Similar work has not developed in the bituminous area of Pennsylvania, doubtless because it is so well covered by the extension work of Pennsylvania State College, previously mentioned.

Company Night Schools

Night schools maintained by mining companies were those of the Lehigh Valley Coal Co. at Lost Creek and Centralia, Pa., and of the Susquehanna Coal Co. at Nanticoke and Shamokin. These were established before the passage of the Pennsylvania Vocational School Act of 1913, and have since been absorbed into the general system of vocational education, which will be described in a moment. In Michigan the Cleveland Cliffs Iron Co. established night schools for miners at Ishpeming, Negaunee, Gwinn, and North Lake in 1912; it was discontinued in 1917 because of the World War conditions. It was especially helpful, from the company standpoint, in developing ordinary employees into electricians at a time when it was greatly increasing its use of electrical equipment, and would otherwise have found it necessary to bring qualified men into the district from outside.

In Arizona the Copper Queen Mining Co. began in 1918, at Bisbee, an evening course for miners, which was announced as "The Road to Promotion." During the first year about one-sixth of the company employees attended some of the 43 sessions, covering a dozen topics ranging from geology to economics, and especially featuring efficiency and industrial problems. Charles A. Mitke, who was chiefly responsible for initiating this work, was subsequently chairman of a committee of the Mining and Metallurgical Society of America, which submitted a report on vocational training for metal miners, which was published as *Bulletin* 149 of the Society (Aug. 31, 1921). This report, while not specifically describing the project at Bisbee, indicates its general aim and outlines specific procedures for such work. It did not survive the depression conditions of 1921 and has not been revived.

Lecture Courses

Lecture courses differ from night schools in being organized wherever and whenever circumstances permit, and in being aimed at those who could not be prevailed upon to embark upon a systematic course of study. So far as possible they utilize visual aids to education, especially lantern slides and moving pictures. The most popular topic for them is safety, though the safety feature is often judiciously diluted with other educational or purely entertaining matter. Most frequent of all are single occasional lectures rather than a course. The motion-picture service of the U. S. Bureau of Mines, which lends educational films without charge from its Pittsburgh Experiment Station, has long been active in this field, and when circumstances permit will send lecturers as well as lend films.

First Aid, Mine Rescue and Safety

The first-aid and mine-rescue training offered by the U. S. Bureau of Mines is unquestionably the most extensive piece of educational work for the mineral industries that has been done by any single agency, but since it is not exactly either a night school nor a lecture course it does not fit into Callen's scheme of classification. When the U. S. Bureau of Mines was organized, in 1911, its first Director, J. A. Holmes, provided for a mine-rescue and recovery service, to lend expert aid in cases of mine explosions, fires, and other disasters. Since very little of the special equipment needed was available in this country at the time, this service was first based upon converted Pullman cars, provided with the equipment and manned by trained men. Later specially built steel cars and, still later, trucks, were employed for this purpose. The cars were routed about through their districts and the district engineer made arrangements for them to spend a week at a property or in a town, where the mining companies would detail certain of their employees to take instruction, on company time, from the staff of the car in first-aid work and in the use of oxygen breathing apparatus. Strict standards were maintained and on the successful completion of this period of intensive instruction a first-aid or mine-rescue certificate was issued to the employee. Between 1911 and 1940, awards totaled 1,291,455 first-aid certificates and 70,010 mine-rescue certificates. The first-aid manual published by the Bureau in connection with this work is the best concise text on that subject.

The mining companies at first provided only for first-aid training of a small proportion of their employees, but as the value of this training in promoting safety in general came to be recognized there arose a demand for every employee to receive it. Eventually the Bureau came to be training first-aid instructors rather than ordinary employees, who received their instruction from the Bureau-trained men. At the same time the Bureau began to develop general safety instruction, with its Pittsburgh station as headquarters, and now carries on work rather like the extension instruction of the mining schools, except that it is limited to safety in mining. The local chapters of the Joseph A.

Holmes Safety Association play a part in stimulating interest in such work; the work of this Association is described in *Informarion Circulars* Nos. 6481, 6095, 6117, 6128, 6137, and 6838 of the Bureau of Mines, but needs to be mentioned here because of its educational features.

Correspondence Courses

The history of the development of correspondence courses in the field of mineral industry education has been thoroughly covered by Stoek in the publication already cited,[60] but perhaps he gave a little too much weight to the influences that led to the development of the International Correspondence Schools of Scranton, and too little to others not directly related to it. Mining publications in England as well as in the United States had long been publishing material of educational value as well as news. The mining law passed in Pennsylvania in 1885, requiring responsible coal-mine employees to pass qualifying examinations, created a sharp increase in the demand for such educational material. T. J. Foster, who had been publishing the *Mining Herald*, a weekly newspaper with a mining department containing educational features, at Shenandoah, Pa., converted it into the *Colliery Engineer*, a monthly publication, in 1887, and the next year moved it to Scranton.

One feature of this paper was a questions and answers department where those preparing for the State examinations were encouraged to ask questions, or to answer the questions asked by others. This proved so popular that in 1891 the staff of the journal undertook the publication of a series of leaflets that could be used as lesson papers by men studying to pass the examinations for assistant mine foreman, mine foreman, and fire boss. These covered surveying, mine gases, ventilation, machinery and mining methods. The first student enrolled in a correspondence course Oct. 16, 1891, and the work grew so rapidly that up to 1914 nearly 50,000 men had taken correspondence mining courses from the International Correspondence Schools, a company organized by Foster to offer instruction in a great variety of subjects of vocational interest. According to the description of this school which appeared in *Fortune* for July 1933, it had enrolled a total of nearly four million correspondence students in the approximately forty years it had been in operation, but this figure may be exaggerated, since figures there given for specific years are about double those furnished by its secretary for this book. In 1929 it did have about 75,000 enrolled correspondence students, but it was seriously affected by the depression and in 1933 the enrollment was only 27,450.

H. H. Stoek took an editorial position with *Colliery Engineer* in 1897, and must have played a considerable part in the development of the correspondence work in mining. Its printed textbooks on mining were models of clarity of presentation; nine volumes were issued in 1900, the last two consisting of tables, formulas, and answers to questions. At first they were kept up to date by revision, but since 1930 the sale of metal-mining courses has been discontinued, the enrollment in that work having been only 40 or 50 for some years previous to the depression. The enrollment in the coal-mining courses also has declined, amounting in recent years to only about one-half of one per cent of the total. Considering that it was the coal-mining work that led to the establishment of the Schools, this is of much interest. Whether it is due to the increase in the work of the Federal Bureau for Vocational Education, to a decline in interest in vocational education in mining, or a combination of both, I have not been able to determine. The only other school offering correspondence instruction in mining of which I can find any record is the Western Mining School of Mining Engineering of St. Louis, mentioned on p. 94 of the Bulletin by Callen.[9] No one in St. Louis seems to know anything about it, and it must have had only a brief existence.

Underground Schools

Underground schools for vocational education for the mineral industries seem to be basically a reaction to a labor shortage, and wither away as soon as an abundant supply of skilled labor becomes available. Since the one established in the Coeur d'Alene in 1918 under the direction of Francis A. Thomson (then dean of the Idaho School of Mines) with the cooperation of the State Board of Vocational Education and the Federal Mining and Smelting Co. is described in some detail in *Bulletin* 38 of the Federal Bureau of Vocational Education, it may serve as a type for underground instruction. Frank H. Skeels, an experienced mining graduate, was placed on a salary basis by the State Board and took a contract for driving a drift with a wholly green crew. The money received for doing the work, after deducting cost of supplies, was divided among the pupil-workmen. A second crew was put at driving a raise. After six weeks of this training, during which they earned about half as much as experienced miners, they obtained regular jobs and a new green crew was started. After the end of the World War, when there was no longer a labor shortage and therefore no need for training green men, the school was discontinued. At the Stag Canon Coal Mining Branch of the Phelps-Dodge Corporation, New Mexico, at about the same time and because of the shortage of coal miners, the manager, T. H. O'Brien, set off one section of the mine for training green men. A published account of this work reported that the mining cost in this section was found to be less than the mine average, and attributed that result to the more careful supervision, especially in systematizing and expediting haulage. It too was discontinued in 1921, but later was revived by W. D. Brennan (who succeeded Mr. O'Brien) with the aim of teaching safety in mining. The second project is described in detail in *Information Circular* 6054 of the U. S. Bureau of Mines.

Probably many other systematic attempts at underground instruction were made in the labor-shortage period of 1917–18, to which no published reference was ever made, but none of them survived after an experienced labor supply became available. Under normal operating conditions the number of wholly inexperienced workers employed by a mineral enterprise in the course of a year is not large enough for the maintenance of an organized training system, and the usual procedure is to put a green man at work as a helper to an experienced one, or to have him given brief instruction by a shift boss, or fellow worker. This is not a wholly satisfactory system, as will be evident, but no better method of dealing with the problem has yet been devised. To maintain a few places in a mine as training rather than production sections would seem practicable, but the emphasis on increasing production, when it becomes necessary, seems to operate to prevent its being done.

Instruction in Placer Mining

After the depression of 1929 there was a great flare-up of interest in placer gold mining among people who were ignorant of it but were unable to secure employment of another kind. Several of the western mining schools met this demand by organizing brief extension instruction courses in various parts of their respective states. Probably not more than 10 per cent of those who sought such instruction were actually engaged in placer mining, and the interest in that work subsided when experience records became available as to the amounts that could be actually earned in placer mining, unless under exceptional circumstances, and work relief became better organized.

Vocational Division of Office of Education of Federal Security Agency

The permanent, extensive organization for vocational instruction for mineral industry work is that* of the Vocational Division of the Office of Education of the Federal Security Agency, which originally was organized as a separate Federal Board of Vocational Education in 1917. The following summary of its activities has been furnished by Giles M. Ruch and Iva G. Prisk:

"An act of Congress approved by the President February 23, 1917 (known variously as the vocational education act or the Smith-Hughes Act), established the principle that the nation as a whole has a share in the responsibility for the vocational education of persons who are preparing to enter, or have entered, trade or industrial occupations, the work of the home, or agricultural pursuits. This responsibility extends also the training of teachers for these types of vocational courses. Direct responsibility for carrying on the work of vocational education rests, however, on the states, and the program may be described as a cooperative one which embraces no direct organization or immediate direction by the national government. Substantial sums of money are provided by this act for allotment to the states, on a matching basis, for the following three purposes:

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* The total of $66,500,000 provided for Emergency Defense Training, under the Office of Education, during 1940 and 1941, is separately organized, but offers some instruction in the mineral industry field, especially in metallurgy. Since it is still in process of development, no attempt is here made to describe it in detail. (See *Journal of Engineering Education,* Sept. 1941, pages 30–56.)

"1. For the payment of salaries of teachers, supervisors, and directors of agricultural subjects.

"2. For the payment of salaries of trade, industrial, and home economics teachers.

"3. For the preparation of teachers of trade and industrial subjects, teachers of home economics subjects, and teachers, supervisors, and directors of agricultural subjects.

"Subsequent acts of Congress extended the provision for vocational education in several respects but only the George-Dean Act need be mentioned. This authorized the appropriation of $14,483,000 additional federal funds for matching state money, effective July 1, 1937. Education for the distributive occupations was specifically provided for by an allotment of $1,200,000, and an additional $1,000,000 was made available for the training of vocational teachers.

"The Federal disbursements to the States for the year ended June 30, 1939 for all purposes of the Smith-Hughes and George-Dean Acts were $19,434,554, and the expenditures of the States and local school districts were $33,233,937; making a total of $52,668,491 which represents the costs of the cooperative vocational education program for the year. It is to be noted that State and local outlays amounted to $1.71 for each dollar of Federal money. The total enrollment in federally aided vocational classes and schools for the same year was 2,085,427.

"According to the census of 1910, nearly half of the miners of the United States were foreign born (432,811). It is estimated that fully three-fourths of these were non-English speaking, and that only a small fraction had been mine workers in their native countries. It was recognized that a problem of education in the English language and citizenship was acute for this working population. On the other hand, two-thirds of the 50,000 negro mine laborers had received a primary education, and 95 per cent of the American-born white mine workers were literate. The foreign-born, making up less than half of the total workers, often accounted for from 70 per cent to 90 per cent of mine accidents.

"Regardless of the amount of general education in these various groups of laborers, all had learned their jobs in the mines—there being no vocational courses for miners at that time. It was also estimated that probably not 25 per cent of miners could undertake a vocational training which required an elementary school education in view of the high incidence of foreign-born and, in certain states, of negroes. Knowledge of the English language was prerequisite to proper instruction in safety measures, not to mention matters of citizenship and assimilation into American social life.

"Specific attention of the Federal Board for Vocational Education to problems of mining education may be dated from the summer of 1918, when Dr. J. C. Wright, then a Federal Agent for Trade and Industrial Education, now Assistant Commissioner for Vocational Education, United States Office of Education, made a study of the opportunities for vocational training in the mining industries. He held conferences with State mine inspectors, mine managers, superintendents, foremen, bosses, and workmen in Colorado, Montana, New Mexico, Oklahoma, and Wyoming. In several of the states the Directors of Vocational Education were found to be working with local mine officials in setting up definite courses of study for the teaching of such topics as mine gases, safety lamps, mine ventilation, mine timbering, shot-firing, mine machinery, and rescue work and first aid. It was thought that the average American-born miner could, by attending an evening class for a period of approximately 24 weeks, 6 hours per week, under the instruction of a qualified teacher, secure enough technical information to enable him to pass the examinations making him eligible for appointment as a boss or foreman.

"A. C. Callen, Director of Extension Instruction for Miners, West Virginia University, was engaged to prepare these courses. He visited many of the largest mining communities throughout the United States, and the following five bulletins were prepared and published in 1919:

Bulletin No. 38. General Mining. Oct. 1919, 169 pages. (Out of print.)

Bulletin No. 39. Coal-Mine Gases. Technical Information for the Use of Vocational Training Classes. Oct. 1919, 36 pages. (Revised, 1931, by N. B. Giles, 41 pages.)

Bulletin No. 40. Coal-Mine Timbering. Technical Information for Use in Vocational Classes. Nov. 1919, 103 pages. (Revised, 1931, by N. B. Giles, 100 pages.)

Bulletin No. 41. Coal-Mine Ventilation. Technical Information for Use in Vocational Training Classes. Nov. 1919, 63 pages. (Revised, 1931, by N. B. Giles, 92 pages.)

Bulletin No. 42. Safety Lamps. Nov. 1919, 72 pages. (Revised, 1931, by N. B. Giles, under the title, Flame Safety Lamps. Devices for Detecting Fire Damp and Miners' Electric Lamps. Technical Information for Use in Vocational Training Classes. 67 pages.)

"The original editions and revisions of these bulletins were reviewed and criticized by members of the staff of the United States Bureau of Mines; special acknowledgment for advice in the initial stages of planning and writing is due E. A. Holbrook and Thomas T. Read. Mr. Callen prepared original *Bulletins* 38 and 39. R. Z. Virgin, then assistant director of the Mining Extension Department of West Virginia University, prepared the first editions of *Bulletins* 40 and 41. Mr. Virgin and Mr. Callen collaborated on the 1919 edition of *Bulletin* 42.

"Courses in mining and metallurgy have been given in vocational schools since the beginning of the vocational program, but the first report on this type of training was made at the close of the fiscal year 1918–19. In that year seven states gave courses in mining which included such subjects as timbering, assaying, mineralogy, mine gases and ventilation for metal and coal mining. In 1939, eighteen states gave courses in mining, including placer and hard-rock mining, first aid, mine rescue, mine safety, mine mathematics, geology, explosives, and mine laws in addition to the subjects taught in 1919.

"Courses in metallurgy have been given in vocational schools since 1919 and include subjects relating to steel production chiefly. Subjects given are, ferrous and nonferrous metallurgy, metallurgy for machine trades, heat-treatment of metals, forging, and metallography.

"The accompanying tabulation (Table 1) shows the growth of instruction under federal stimulation by five-year periods from 1919 to 1939.

"Detailed tables showing growth of the mineral industry instruction 1919–1939, and its distribution of states and subject matter are given herewith." (Tables 2–4.)

TABLE 1.—*Number Centers, Teachers; Enrollment and Reimbursement in Mining Courses, Vocational Education*

Year	Number of Centers	Enrollment	Number of Teachers	Reimbursement
1919	29	814	32	$ 1,114.19
1924	133	4,010	132	20,563.02
1929[a]	126	4,236	92	23,605.98
1934	200	8,335	150	22,222.08
1939	359	16,688	402	70.122.19

[a] In addition, Colorado reports for 1929 in first aid: centers, 35; enrollment, 5,910; teachers, 35; reimbursement, $1,840.68.

TABLE 2.—*Mining Courses in Federally Aided Vocational Schools and Classes*

Year Ended June 30	Number of Centers	Number of Teachers	Enrollment
1919	21	32	814
1920	40	54	1,010
1921	66	77	1,519
1922	102	76	3,198
1923	107	97	3,147
1924	133	132	4,010
1925	129	154	5,347
1926	109	110	7,776
1927	110	165	7,220
1928	118	176	7,544
1929	158	127	10,146
1930	163	184	9,946
1931	160	289[a]	11,757
1932	183	362[a]	15,045
1933	215	374	13,095
1934	200	150	8,335
1935	240	280	11,558
1936	299	339	12,047
1937	295	273	13,379
1938	342	336	16,986
1939	346	386	16,642

[a] Teachers of different courses. The number reported included one teacher for every class; in 1932, 441; in 1931, 516.

It is evident that most federally aided vocational education is given in coal-mining states. Two obvious reasons for this are the usual requirement of passing an examination in order to

TABLE 3.—*Type and Subject of Mining Courses Given in Federally Aided Vocational Schools*

Type and Subject of Course, 1919	State	Type and Subject of Course, 1939
(Evening classes in mining and mine timbering begun in 1922)	Alabama	Evening classes: Mining Mining arithmetic Ventilation and mine gases Mining laws and map reading Practical mining arithmetic General mining
	Alaska	Part-time classes: Placer and hard rock
Evening classes: Mineralogy Assaying	Arizona	
Evening classes: Mining mathematics	Colorado	Evening classes: First aid Coal-mine foremanship Coal-mine rescue Coal-mine shot firing Coal-mine safety Mine rescue Mine safety Mine surveying Shot firing Mine gases
Evening classes: Underground mining	Idaho	Part-time classes: Drafting Mathematics Mineral identifying and assaying
(Evening classes in coal mining begun in 1920)	Indiana	Evening classes: Mine maintenance Part-time classes: Save coal production Mine gas and ventilation Day classes: Mine maintenance
Evening classes: Mining Assaying Mineralogy Mine surveying	Kansas	
	Kentucky	Part-time classes: General mining Day classes: Mining mechanics Related mathematics and science
	Maryland	Part-time classes: Accident prevention Mine electricity Mine ventilation Electricity and maintenance

TABLE 3.—(*Continued*)

Type and Subject of Course, 1919	State	Type and Subject of Course, 1939
	Missouri	Part-time classes:
		Engineering, mathematics
		Mechanical drawing
Evening classes:	Nevada	Part-time classes:
Mining		Mining subjects
		Prospecting
	Ohio	Coal mining:
		Gases
		Mine laws
		Science
		Mathematics
		Geology
		Ventilation
		Drainage
		Electricity
		Timbering
		Explosives
		Haulage
	Oregon	Evening classes:
		Practical geology and mining
Evening classes:	Pennsylvania	Part-time classes:
Mining		Bituminous mining
		Mining methods
		Closing and vamping
	South Dakota	Evening classes:
		Explosives-miners
		Mine drafting, layout
		Steel erection
		Carpenter's layout
	Tennessee	Part-time classes:
		Mine ventilation
		Mine gases
		Mine timbering
		Characteristics of coal
		Mine mathematics
		Mine reports
		State laws
		Foremanship
		Mining methods
		Trackage and haulage
		Applied electricity
		Explosives and blasting
		Drainage
		Job analysis
		First aid
		Electricity
	Utah	Evening classes:
		Welding for mining-machine repair
		Western coal-mine practice
	Virginia	Part-time classes:
		Coal mining

TABLE 3.—(*Continued*)

Type and Subject of Course, 1919	State	Type and Subject of Course, 1939
Evening classes:	West Virginia	Evening classes:
Mining		Mine blueprint reading
		Math. for mine electricians
		Essentials of electricity
		Mining subjects
		Foremanship
		Haulage, drainage, and pump
		Electricity
		Part-time classes:
		Mine mathematics
		Mining subjects
		Mine ventilation—fires
		Explosives—mine gases
		Safety lamps
		Day classes:
		Mine maintenance
		Machine shop
		Welding
		Pipe fitting
(Evening class in mine ventilation given in 1920)	Wyoming	Evening classes
		Coal-mine foremanship
		Mineralogy
		Prospecting
		Mining electricity
		Gas watchman
		Safety first
		Coal mining:
		Gas watchman
		Inspector
		First aid
		Part-time classes
		First aid and safety

qualify for employment as shot firer, shift boss, or foreman, and the relatively greater number of employees in coal mining than in metal mining. The subject matter of the courses given reflects this condition, as does the relative enrollment, which is largest in a prospecting course in Nevada and Utah, whereas in the coal-mining states the chief enrollment is in courses covering matters embraced in the qualifying examinations.

CONCLUSION

If one were to attempt a review of experience in subcollegiate and vocational education for the mineral industries in the United States the conclusion seems inevitable that apparently there is

TABLE 4.—*Enrollment in Mining Courses in Federally Aided Vocational Schools and Classes*

FISCAL YEAR ENDED JUNE 30, 1939

State	Subject of Course	Enrollment	
Alabama	Mining	2,179	
	Mining arithmetic	1,896	
	Ventilation and mine gases	49	
	Mine laws and map reading	49	4,173
Alaska	Placer and hard rock		673
Colorado	First aid	538	
	Coal-mine foremanship	126	
	Coal-mine rescue	186	
	Coal-mine shot firing	75	
	Coal-mine safety and mine safety	411	
	Mine surveying	14	
	Shot firing, mine gases	132	
	Mine rescue	15	1,497
Idaho	Drafting	10	
	Mathematics	10	
	Mineral identifying and assaying	10	30
Indiana	Machine shop, mine maintenance	41	
	Save coal production	136	
	Mine gas and ventilation	183	
	Mining, ventilation	29	
	Mine ventilation	15	404
Kentucky	General mining	1,423	
	Mining mechanics, related mathematics and science	22	1,445
Maryland	Accident prevention Mine electricity Mine ventilation	100	
	Mining ventilation Electricity and maintenance	76	176
Missouri	Engineering mathematics	30	
	Mechanical drawing	26	56
Nevada	Mining subjects	106	
	Prospecting	453	559
Ohio[a]	Gases		
	Mine laws		
	Science		
	Mathematics		
	Geology		
	Ventilation		
	Drainage		
	Electricity		
	Timbering		
	Explosives		
	Haulage		272
Oregon	Practical geology and mining		140
Pennsylvania	Bituminous mining methods	2,012	
	Mining methods Closing and vamping	29	
	Mining methods	294	2,335
South Dakota	Explosives, miners	21	
	Mine drafting, layout	15	
	Mine steel erection	13	
	Mine carpenters layout	11	60

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[a] In West Virginia, Tennessee, and Ohio, the enrollment reported included two or more courses and separation by courses was impossible.

TABLE 4.—(*Continued*)

State	Subject of Course	Enrollment	
Tennessee[a]	Mine timbering		
	Characteristics of coal		
	Mine ventilation		
	Mine reports		
	Mine mathematics		
	First aid 4		
	State laws		
	Mine gases		
	Trackage and haulage		
	Mining methods		
	Foremanship		
	Applied electricity		
	Drainage		
	Explosives		
	Job analysis		
	Explosives and blasting		993
Utah[b]	Welding for mining }	14	
	Machine repair }		
	Western coal-mine practice	51	
	Prospecting	157	222
Virginia	Coal mining		771
West Virginia[a]	Mine blueprint reading	59	
	Mathematics for mine electricians	44	
	Ess. of ele. for mine electricians	30	
	Miners subjects	346	
	Foremanship	154	
	Haulage, drainage and pump	212	
	Electricity	103	
	Mathematics	123	
	Mine fire boss and foreman	293	
	Explosives and mine gases	763	
	Safety lamps	416	
	Mine ventilation and fires	49	2,592
	Railway and mine maintenance		
	Machine shop		
	Welding		
	Pipe fitting		
Wyoming[b]	Coal-mine foremanship	{ 23 { 26	
	Mineralogy, prospecting	20	
	Mining, electricity	11	
	Gas watchman	65	
	First aid	19	
	Mining inspector	21	
	Coal mining	21	
	First aid	20	
	First aid and safety	18	244
Total enrolled in all courses			16,642

little place for anything between full-time technical education of collegiate grade and part-time vocational education. The writer is inclined to agree with E. A. Holbrook, who believes that the general American viewpoint makes impossible the success of any school that offers only a limited program. Parents are incensed at any suggestion that their children are not qualified for the highest type of education, and the students themselves fear being considered second-rate. Experience seems to confirm this belief. Small schools of limited scope may persist where local conditions favor their existence.

It also seems impracticable to conduct vocational education on a centralized basis; that is, from a vocational school building. The Freeland Mining and Mechanical Institute, established as a vocational school for miners, has become an ordinary private college-preparatory school of high-school grade. The Wisconsin Mining Trade School, established as a subcollegiate mineral industry technical school, has become an Institute for general engineering instruction, and evidently is developing toward an ordinary four-year engineering school. The schools at Tonopah and Ely, Nevada, have persisted but not grown, and the one at Kilgore, Texas, is still in the experimental stage. Successful vocational education is typically based on providing qualified instructors to go out and hold classes wherever a sufficiently large group of students can be gathered together, utilizing whatever space facilities may there be available.

The system which has been developed, of Federal aid to State educational agencies, and the conduct of mineral industry vocational education as part of general State vocational education, seems to be well adapted to the actual situation. The U. S. Bureau of Mines functions to stimulate interest in safety and first-aid instruction, and maintains high standards for it by giving enough such instruction itself to ensure that result. The management of mineral enterprises no longer attempts to give vocational instruction on company account but in some cases exhibits a keen interest in promoting and supporting it, ranging on down to almost complete indifference to it. Wherever and whenever an enterprise experiences no difficulty in securing a sufficient supply of experienced and qualified workers, the latter attitude is quite understandable, on the principle that "it is the squeaking wheel which gets the grease." In times of marked labor shortage or in places where there is a sudden demand for a type of labor not previously required, company interest in the problem becomes accentuated, and may result in local, usually temporary, activities.

Re-education of employees because of shifts in vocational opportunity has not been mentioned, nor have foreman-training courses. These are two of many other aspects of what is really a very complex educational problem. It is idle to suppose that any "system" will ever be devised which will completely satisfy every aspect of it. What is necessary is to avoid anything so rigid that it cannot be easily modified to meet changing needs, to be awake to changes in needs as they occur, and to foresee them whenever possible.

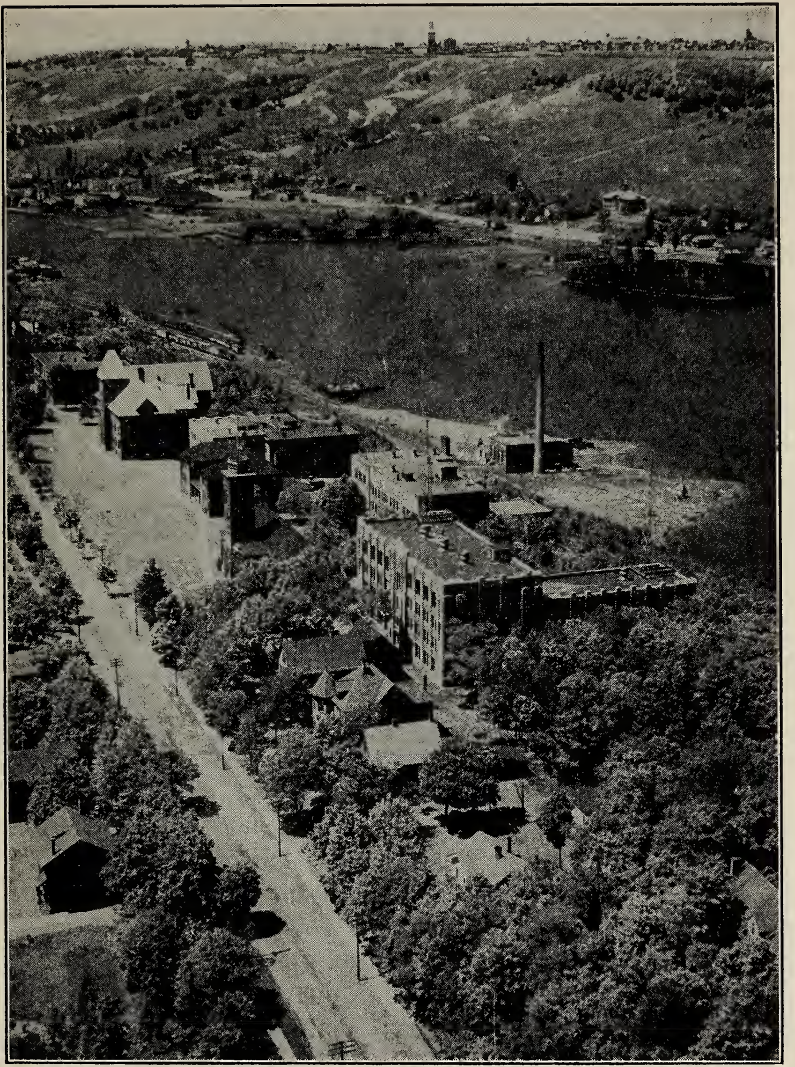
CHAPTER 15

SUMMARY

DESIRABLE as it is to summarize what has been set forth in preceding chapters, the task can only be approached with great hesitation. What follows represents the personal views of the author at the moment of writing, reserving the privilege to change them on more mature reflection or in the light of further evidence. With that reservation they may be stated somewhat as follows.

Education for the mineral industries falls into two categories; general education and technical vocational, using the word vocational not in its usual sense but to signify preparation for specific activities, in which sense a law school is a vocational school. Even at the beginning, as indicated in the first chapter, mineral industry education was partly general and partly technical and that relationship still persists, because technical education requires a firm basis of general education. Our general American system is to provide free public general education through the twelfth grade, or completion of high-school work, though there are already many technical vocational high schools, and even in a community where nearly all the young people are preparing for entrance to college there will be some who wish to qualify for employment at the end of the high-school course, or even on completing junior high. Our educational system, therefore, has not only to provide education for those who intend to proceed beyond the twelfth grade but also for those who, for a variety of reasons, may wish or be forced to cease full-time education at any level between the first and twelfth grades.

This study has been chiefly concerned with the problem of what kind and how much technical education to provide for those who have completed the twelfth grade and who wish to make their living in the mineral industries. The obvious fact that the mineral industries employ all sorts of trained persons,



Michigan College of Mines.
Aerial photograph by Abrams Aerial Survey Corporation, Lansing, Michigan.

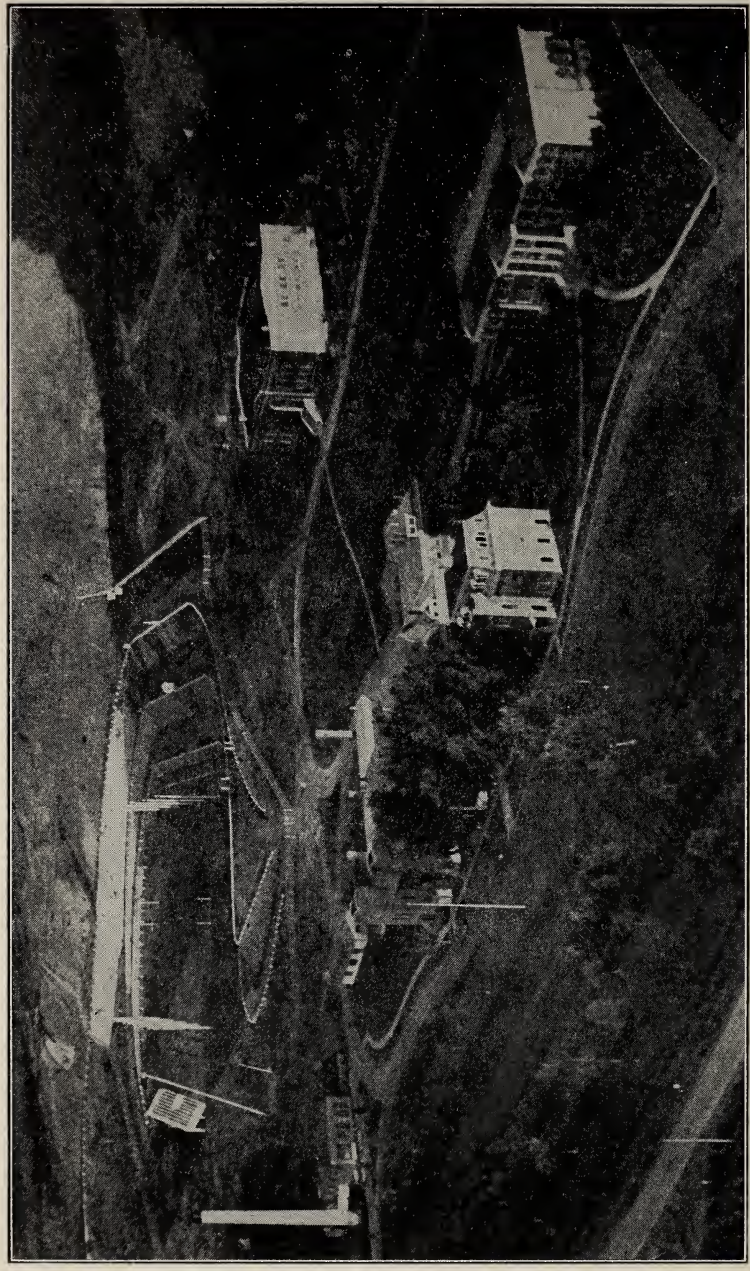
accountants, doctors, nurses, salesmen, etc., has been ignored, since we are here concerned only with the education peculiar to the mineral industries. Vocational education, in the ordinary sense of that word, was briefly discussed in chapter 14 merely in recognition of its importance in the general educational scheme; it might properly be the subject of a separate book.

Education for the mineral industries had been developing in Europe for more than a hundred years before it was initiated in the United States, at Philadelphia in 1853, by an institution which is no longer in existence. In Europe it had taken two forms; vocational education for working men and technical education at the collegiate level for officials in a state-controlled and usually state-owned mineral industry. The former was largely ignored here, and our institutions of collegiate grade organized their curricula on the European pattern, regardless of the fact that our political, economic, and social conditions were quite different from those of France and Germany, where mineral industry education was most highly developed. This was not so important as it might at first seem, since the most significant feature of such education at the time was the acquiring of a knowledge of natural science, and of its applications to the problems of human life.

The first attempt to establish systematic mineral industry education in the United States was a failure, and it was not until a School of Mines was established in New York in 1864, in connection with Columbia College, that real success was attained. Within the next few years Harvard attempted to offer mineral industry education, without result, and a second trial at Yale was no more effective than the first. The State Universities of Wisconsin and Illinois began offering such instruction, only to drop it within a few years, while the outcome at the University of Michigan differed only in that the initial efforts were more encouraging and the final demise was longer delayed. Some of the other institutions fared better, but the net result was that during the 25 years following the granting of the first degree in mining by Columbia in 1867 half of the total number conferred in the United States had been given by that institution, although at least a score of others had been offering the instruction in that field.

The reasons for the initial success of this instruction at Columbia, and the contrasting results at the other institutions (which at first ranged from flat failure to at best only moderate achievement), seem to be as diverse as they are obscure. In some cases faulty academic organization hampered progress; in others much of the curriculum existed only on paper, for there was no one really qualified to teach the technical subjects ostensibly offered; and perhaps the most important reason was that in some regions there was no demand by young men for the kind of curriculum offered. Though Columbia offered separate curricula in metallurgy and geology almost from the beginning, and was in reality a school of technology, teaching both civil engineering and the then equivalent of chemical engineering, it was universally regarded as a School of Mines, and consequently was considered a demonstration that organization of separate schools of mines was perfectly feasible. The flow of American students to European institutions practically stopped, and the number of places at which adequate instruction could be obtained in the United States steadily increased.

In the early nineties there was a great renaissance of interest in mineral industry education, especially in state-supported institutions and in areas where mining was the principal industry. Hampered at first by inability of the public school systems of their regions to supply a sufficient supply of adequately prepared students, and always confronted with the practical problem of supporting separate developments of mathematics, physics, chemistry, etc., instead of being able to draw upon the resources of adequately staffed university departments, separate Schools of Mines endeavored to maintain and develop an ancient and honorable tradition. Their problem was complicated by the simultaneous trend toward diversification in mineral industry curricula, and the demand from local students for instruction in ordinary functional engineering curricula. The result has been that of all the separate institutions originally established here as Schools of Mines only two remain which limit themselves to mineral industry education. Both are publicly supported institutions in states where mining is the industry of most vocational interest, and both are part of a State system which divides the whole field of higher education into segments physically dis-



State School of Mines, Rapid City, South Dakota, 1940.
Note football stadium with provision for watching game from cars parked on terrace.

tributed throughout the state with consideration of at least geographical (if not to say political) as well as educational considerations. Two have frankly become* schools of general engineering technology, while retaining the name of School of Mines, and the subdivision of Columbia University changed its name to School of Engineering in 1926 to conform to the long-existing facts of academic organization. In general, it may be concluded that physically separate schools of mines have not proved to be the most satisfactory form of organization for mineral industry education in the American pattern for higher technical education.

By far the greater number of schools of mines were never physically separate institutions, but were established in connection with, or as a part of, some larger educational organization. Three of the early schools established in connection with state universities quickly went out of existence, though all three later revived mineral industry education as departments in their engineering schools. At the Massachusetts Institute of Technology mineral industry education was from the first merely one department of the Institute's organization. The Columbia School of Mines, on the contrary, almost from the beginning was a school of general engineering technology, and as curricula in architecture, electrical, mechanical, and chemical engineering were successively added to its original five curricula (mining, metallurgy, geology, chemical technology, and civil engineering) the pressure to change its name became too great to be resisted, though the name School of Mines has been retained for the mining and metallurgical departments as a division of the University's Engineering School.

This relationship has introduced a difficulty which has not yet, I believe, been sufficiently clearly recognized. Where mineral industry education is organized as a division of general engineering instruction there is an inevitable tendency to regard it as merely one form of general engineering technique. This is an almost complete abandonment of the original concept of education for the mineral industry, which was a preparation for the proper conduct of the industry, though in actual practice the most important instruction dealt only with natural science and its applications to mineral technology. Whatever the limitations of the actual mineral industry curriculum were it was at least based on a recognition of the self-evident fact that mineralogy and geology bear about the same relation to mining engineering (using the term in its broadest sense) as anatomy and *materia medica* bear to the practice of medicine. Electrical, mechanical, and civil engineers not only typically lack knowledge of these basic sciences, but until recently exhibited no consciousness that they were of more significance to others than to themselves. Well-developed and effectively functioning departments of geology and mineralogy are essential to organized mineral industry instruction, but are of hardly as much significance to a general engineering school as an English department. Mineral industry education is not simply engineering applied to the production and utilization of mineral substances, but that basic fact is not likely to be recognized where it is organized as merely one branch of the work of general engineering school.

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* The Missouri School of Mines was from the beginning a general technical school, with special emphasis on mining.

This matter tends to be further confused rather than clarified by the tendency, of recent years, to broaden general engineering instruction on the ground that a really well-educated engineer must be an economist and business man as well as trained in engineering. This would apply to mineral industry education, and therefore tend to unify it with general engineering education. It must be evident that no one can have an effective understanding of the economic and business aspects of the mineral industry without an adequate knowledge of mineral substances and their structural and geographic characteristics. The author is of the opinion that elementary instruction in the principles of economics and business is of little value to any kind of engineer, and that at least so far as mineral industry education is concerned any effective grasp of the principles of economics and business can only be acquired by the "case method," which illustrates them through the study of actual situations. Mineral industry education is not one of many species of general engineering; to use a biological term, it belongs to a different genus than that to which electrical, mechanical, and civil engineering belong.

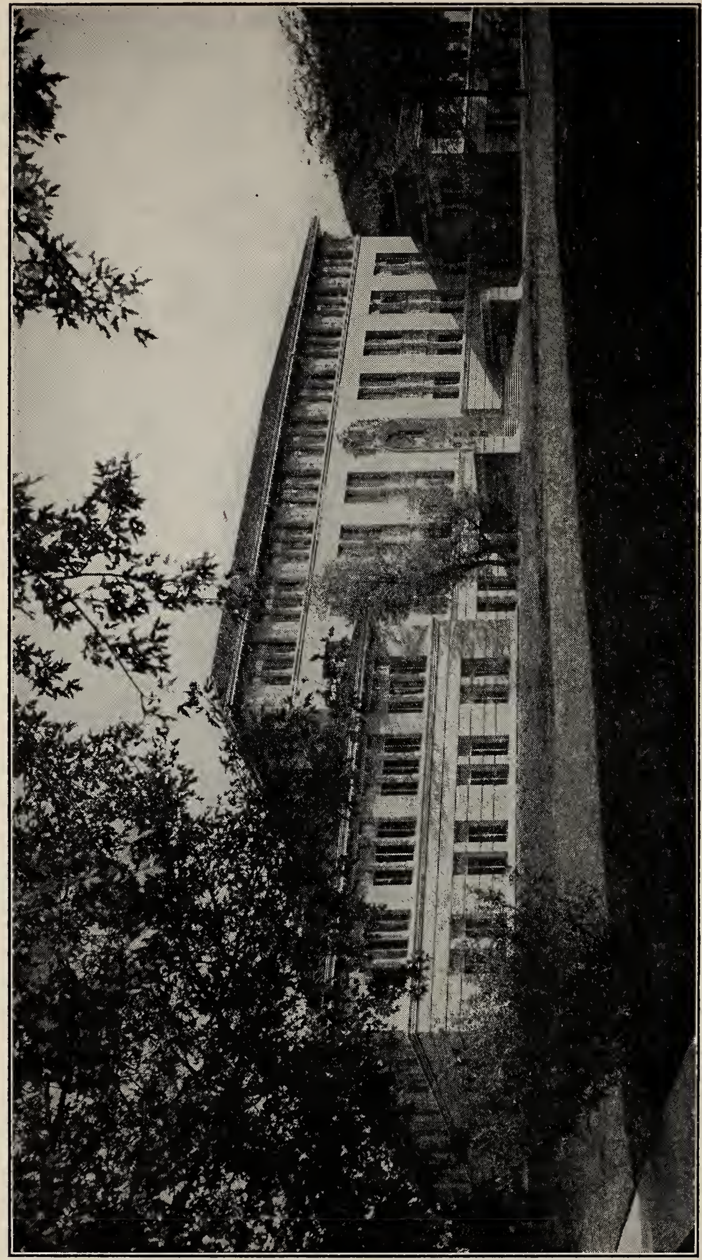
Perhaps for this, and for other reasons we will not attempt to go into, specific mining engineering instruction has not developed as these other branches of engineering have. Until recently courses in "mining methods" were merely descriptions of how mining is actually done. Even the civil engineers, who are also a backward group, would not confine a course in bridge construction to a mere description of how bridges are actually built, without attempting any analysis of why they were built as they were instead of in some other way. This serious defect of mining (using the word in its narrow sense) instruction is now being remedied, and there is in process of development a true mining engineering, as distinguished from the application of other ordinary engineering techniques to the problems of mineral extraction. Metallurgy passed through this stage of its development much earlier. A clear understanding of this matter is hampered by the confusing use of the term "mining engineer" in two different senses, the one in which it has just been used and the more common one of referring to anyone with technical knowledge of the mineral industry as a mining engineer. One of the first professors of mining engineering was simply an economic geologist, and even today many persons are considered mining engineers who have had no systematic engineering training, though they may have learned in the school of experience.

This brings us to the problem of "practical" mineral industry instruction. It will be remembered that the early instruction in this field was definitely intended to prepare for the supervision of an industry. In the course of time technical knowledge has so increased, especially in the fields of metallurgy and economic geology, that fields have developed for the employment of men whose duties are technical advisory instead of administrative, and in metallurgy a large field has developed for research investigators. Nevertheless, the impression still prevails in many quarters that mineral industry instruction should be "practical." From time to time this has evidenced itself through the appointment as professors of mining and metallurgy of men who have attained marked personal success in industry. Without exception this has proved to be a mistake, not merely because such men are not qualified teachers but because they come to their tasks with wrong ideas as to what schools should attempt to teach. It should be self-evident that a school not only cannot effectively teach a young man how to operate an iron blast furnace, but it should not attempt to try to do it, for an ineffective attempt to reproduce actual operating conditions in a laboratory serves to confuse a student rather than to enlighten him. The place to learn practice is in the places where it is actually being carried on, and mineral industry education has not yet, and perhaps never will, develop an equivalent for the interneship of a practicing physician. When, and if, it does develop it must be in the plants rather than in academic institutions, and the problems involved are so complex that we cannot follow them further here. The fact remains that an academic institution is a place for giving academic instruction; to hybridize it by attempting to make it simultaneously a school of practice has the sterilizing effect that hybridization always produces.

Another idea which has had a harmful effect on the development of mineral industry education is that a mineral industry school needs to be practically on top of mines in order to be effective. It might be true if the proper aim of such schools were to teach practice, but it has reacted to prevent recognition of the fact that schools should have no such aim, as argued above. One practical reason for the existence of a mineral industry school in an area where that industry offers the principal vocational interest is that it provides local, and correspondingly inexpensive, instruction in a region where the demand for it exceeds the average. This may tend to react to cause the supply of graduates to exceed local demand. Up to the nineties the graduate of an eastern mineral industry school typically went to the western states to obtain employment; of recent years the graduates of western, as well as eastern, schools have been increasingly finding employment in eastern mineral industries. As early as 1893 S. B. Christy argued that a half-dozen mineral industry schools would be ample to provide 200 graduates yearly. In 1938–39 there were 1063 fourth-year students enrolled in 49 institutions which were offering mineral industry instruction, omitting those who were enrolled in specialized petroleum courses and the institutions that offer instruction only in that field. The present ratio of institutions to graduates is therefore nearly double Christy's figure, and the discrepancy is even more striking when one remembers that he was talking of mining engineering graduates, and there were 332 fourth-year men in mining engineering curricula in 1938–39. The academic situation is not quite as bad as is the economic one regarding gasoline filling stations, but a similar tendency toward overmultiplication evidently exists, and should be resisted.

An interesting development in the field of mineral industry education is the relatively recent discovery by engineering schools that mechanical engineers need sufficient knowledge of metallurgy to understand the nature and properties of the materials with which they must work. Civil and electrical engineers are tending in the same direction, but less rapidly. The chemical engineers had come to the same conclusion earlier, but their general reaction to it was to claim that metallurgy is merely a special branch of chemical technology, and therefore a part of their own field. The reactionary attitude of some metallurgical departments, which continued to think of that field merely in terms of process metallurgy (the production of metals from their ores), contributed to a confused situation, which has recently been made more complex by an attempted redefinition of mineral dressing as covering the whole field of the treatment of minerals to fit them for use as the raw materials of construction, thus embracing the whole of process metallurgy. No one can foresee yet what the final outcome of this will be, but to the author it seems unlikely that mineral dressing as a curriculum will carve out from the fields of chemical and metallurgical engineering enough to form a greatly enlarged empire for itself. It is, however, true that many of the special curricula that have developed have large borderline areas which they necessarily share with others. We have also seen in preceding pages that, for example, chemical engineering departments in areas where petroleum refining is practically the only chemical industry may be essentially departments of petroleum refining.

This introduces two points—that curricula have become diversified in response to vocational opportunities, and that the character and extent of diversification depends upon vocational opportunities in the area which the institution serves. Mineral industry education will never exhibit that degree of standardization which is characteristic of mechanical and electrical engineer-



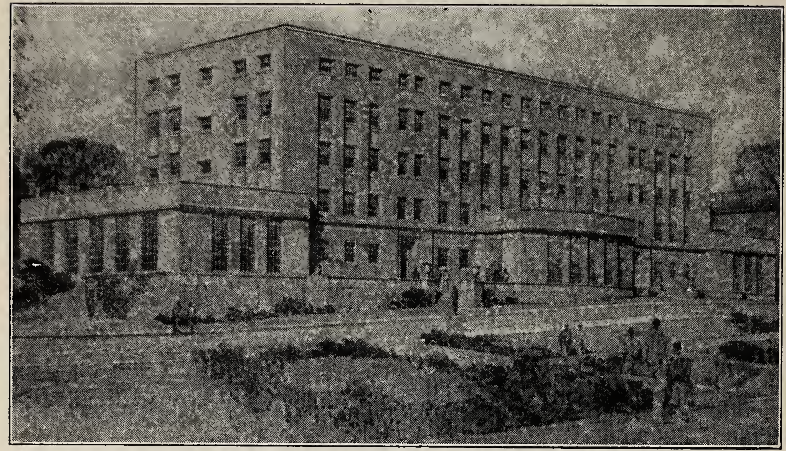
Berthoud Hall, Colorado School of Mines, 1940.
Chiefly houses the Geology Department.

ing curricula. This is another reason why it seems unwise to include mineral industry education as a mere division of general engineering instruction in a large educational institution. The fundamental bases and objectives of mineral industry education are sufficiently different from general engineering so that it should, wherever possible, be organized as a separate school, college, or whatever the local term may be. The writer believes that such an educational unit should be known as a School of Mineral Industries, rather than as a Mining School, to make clear that it covers the field of ceramic engineering as well as metallurgy and petroleum technology, and that it should include economic geology and mineralogy in its departments.

The problems of whether curricula covering four years beyond the twelfth grade are in general adequate educational preparation for the mineral industries, whether five-year curricula are better, and to what extent graduate work, leading to the doctor's degree, is desirable, have been discussed, but only tentative conclusions can be reached. Experience indicates that basing technical work in this field upon two or more years of ordinary collegiate education is in general a too advanced ideal at the present time, and perhaps may never prove generally practicable and desirable. Certainly we shall have to continue, as in the past, to make haste slowly, gradually adjusting curricula to the demands of the time and place, always with the aim of better preparing young men to perform the work that they are likely to find opportunity to do. If this work is to be done really well it will be by young men who have been given a sound appreciation of the part which mineral industry has played in the development of civilization, and its proper place in modern society. Their technical knowledge must be based upon a sound and thorough grasp of the fundamental principles and natural facts underlying it. Beyond that, they must have a clear appreciation of their duties to and responsibilities in a social order which supports them as they support it; in short, be broadly educated. Toward this ideal mineral industry education has tended to advance since it was first initiated in the United States.

In the report on technical education made by the committee appointed for that purpose by the Mining and Metallurgical

Society, in 1921, it is said that "Character, human sympathy, vision, clear thinking and force, are after all the alphabet that spells success for an engineer and for a citizen, and afford that personal satisfaction which is the chief goal of existence. Courses under these headings are not listed in the catalogs of our mining schools. Perhaps a formal instruction in them is impossible; yet obviously they must not be neglected. They are to be acquired, chiefly through the deliberate or unconscious outgivings of the really big men in the faculties, men who themselves possess these priceless talents and have the personality to make their impress felt on those around them. . . . . . The unblemished personal reputations enjoyed by engineers almost without exception is an enviable commentary both on the quality of their teachers and on the fundamental soundness of a training in science, which is nothing more than a search for Truth." In suggesting that aptitude for excellence in these characteristics inheres in the original germ plasm of the individual, and that training for their development should begin in the cradle rather than at the twelfth grade level, I find myself in complete agreement with the committee that mineral industry education in this country deserves high commendation from that viewpoint. A



Mineral Industries Building, West Virginia University, now under construction.

suitable epitaph for the men who have been responsible for its development might be "Si monumentum requiris, circumspice."

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